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(71)(72) Applicant and Inventor: FRAUGHTON, Edward, J. [US/US]; 10353 South 1300 West, Salt Lake City, UT 84065 (US).

(74) Agents: NYDEGGER, Rick, D. et al.: Workman, Nydegger & Jensen, 1000 Eagle Gate Tower, 60 East South Temple, Salt Lake City, UT 84111 (US).

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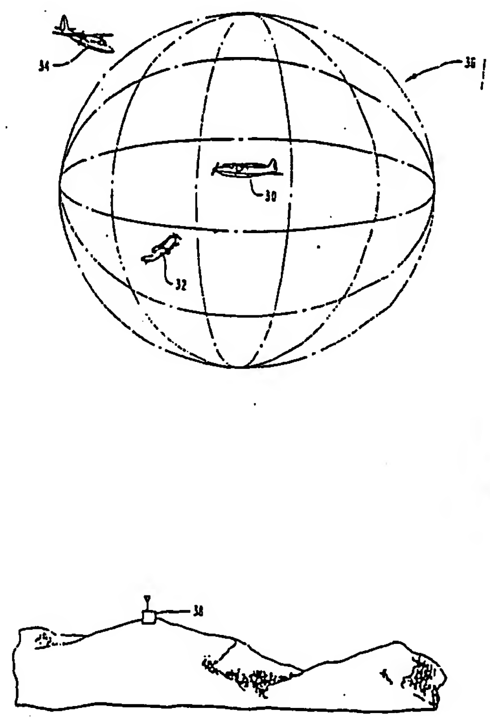
(54) Title: A UNIVERSAL DYNAMIC NAVIGATION, SURVEILLANCE, EMERGENCY LOCATION, AND COLLISION AVOIDANCE SYSTEM AND METHOD

(57) Abstract

A craft tracking and collision avoidance system is disclosed. The system allows the positions of a plurality of craft (30, 32) either on land, sea, air or space, to be monitored. Each craft (30, 32) determines its own position using an existing position determining system (100) such as LORAN or GPS. Each craft (30, 32) then transmits a radio frequency signal into which position information, preferably identifying information and other messages, have been encoded. Each craft (30, 32) broadcasts its position, identifying information and other messages on a regular basis without the need for any interrogation signal. The broadcast position and identification information can be received by other craft and, since each craft (30, 32) has determined its own position, can be used to determine the proximity and identity of other craft, and if the craft are on a collision course. Preferably, the position of all the craft (30, 32) within a predetermined range (36) of a craft (30) is represented on a display in order to give the craft operator a visual indication of traffic surrounding his craft (30).



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A UNIVERSAL DYNAMIC NAVIGATION, SURVEILLANCE, EMERGENCY LOCATION, AND COLLISION AVOIDANCE SYSTEM AND METHOD

BACKGROUND

1. The Field of the Invention.

This invention relates to systems and methods for automatically announcing the position of one or more mobile craft to a receiver positioned at a remote location. More particularly, the present invention relates to systems and methods for tracking the positions of a plurality of mobile craft so as to provide assistance in navigation, surveillance, emergency location and collision avoidance.

2. The Prior Art.

Throughout recorded history there has been an ever increasing need for more precise navigational aids. Through the years, the time keeping and position determining devices used for navigation have evolved from sun dials and sextants to sophisticated digital electronic systems capable of providing nearly pinpoint positioning accuracy almost anywhere in the world.

In today's transportation and communications environment, many devices exist that provide specific navigational aid to the operators of air, sea, and land craft. Navigational aids such as the Global Positioning Satellite system (GPS), the Long Range Navigation system (LORAN), and other navigational aids commonly referred to by such various acronyms as: VOR-DME, VOR-TACAN, DECCA, OMEGA, NDB, ILS, MLS, and ADF, are used by craft operators, particularly aircraft pilots, to determine the position of their craft in one, two, or three planes in space. For example, an operator of an aircraft may only desire to know the position of the craft above or below the surface of the earth (altitude or depth) or may desire to know only the

position of the craft relative to a fixed terrestrial reference system (latitude and longitude) or the operator may desire to know the craft's position in all three planes in space.

One of the purposes of the various available navigational aids is to allow operators of craft, in particular air and water craft, to avoid collisions between their craft. As is well known, mid-air collisions of aircraft almost always result in disastrous loss of life and property. In an effort to avoid collisions between craft, various systems have been implemented in the air and marine transportation industries.

In the United States, government agencies dealing with the air transportation industry have recognized a need to prevent mid-air collisions. In an effort to reduce the occurrence of mid-air collisions, U.S. government agencies have mandated that by the end of 1991 all commercial aircraft with thirty or more seats be equipped with collision avoidance equipment. Several types of collision avoidance equipment have been devised and are classified as either "active" or "passive" systems. These systems are commonly designated as Traffic Alert and Collision Avoidance Systems, also referred to as TCAS.

TCAS has been designed as a primary collision avoidance system for commercial aircraft and has received the United States Federal Aviation Administration's approval. An "active" TCAS system (TCAS II or III) provides the capability to interrogate other nearby transponder-equipped aircraft to elicit a responsive reply, while "passive" TCAS systems (TCAS I) simply eavesdrop on nearby interrogation replies from other transponders. In order to detect a "bearing," a TCAS system requires an expensive directional antenna.

The TCAS method is dependant upon either a secondary or beacon surveillance radar system, or other transponder (S) type interrogations in order to elicit a responsive reply. It is also transponder dependant, meaning that any aircraft not equipped with a transponder will not be detected, and any transponder not coupled to an altitude encoder will not deliver altitude information.

Recently, serious questions have been raised about how "safe" TCAS is in practice. TCAS operates in a narrow band of Air Traffic Control (ATC) radio frequencies in the microwave region of the spectrum. Thus, because of the number of interrogation requests and replies elicited, and the amount of information needed to be processed both TCAS and the ATC system may be "overwhelmed," and their operation sufficiently degraded to the point of "saturation," where the number of aircraft under the control of ATC exceeds the capacity of the system. Already, computer overloads and radar shutdowns have occurred at some busy locations. There is also the danger of a malfunction occurring, such as an item of interrogation equipment becoming stuck in the transmit mode, thereby "locking up" the entire system.

The high cost of the on board TCAS equipment makes its installation prohibitively expensive to most aircraft other than commercial aircraft. Moreover, TCAS III has not yet been fully developed. Even further, TCAS II and III are designed with the commercial aviation market in mind, but of the 215,926 active aircraft registered in the United States in 1988, the commercial aviation fleet only amounted to about three percent (3%) of the total. Thus, it is apparent that improved collision avoidance systems need to become more accessible to a much larger portion of the aviation industry, as well as to land and sea-based craft.

In view of these drawbacks and difficulties it would be an advance in the art to provide a complete traffic control system not requiring radar, and which provides a system and method for announcing the position of a craft to a remote receiver such that the position of the craft can be continuously monitored and collisions with other craft avoided. It would also be an advance in the art to provide a system and method for collision avoidance which may be used in addition to, and without interference with, preexisting collision avoidance systems and which can be economically implemented in the general aviation and marine industries so that, for example, with a single frequency select switch sea-going vessels could monitor air or land-based traffic and vice versa.

It would be a further advance in the art to provide a system and method which allows the operator of a first craft to monitor the position of a plurality of other craft within a predetermined range of the first craft and to alert the operator of a craft of a potential collision between craft as early as possible. It would be yet another advance in the art to provide a system and method for announcing the position of craft to other craft which are within a predetermined range which is reliable, does not distract an operator of a craft from other duties, and provides short and long range navigational assistance to the operator of a craft.

It would be a still further advance in the art to provide a system and method of tracking the position of one or more craft within a predetermined range of a location anywhere on the earth such as at a remote airstrip, or beneath the surface of the ocean, or in space. It would be an even further advance in the art to provide a collision avoidance system which does not become saturated in areas of heavy traffic and which is capable of assisting with the

landing or mooring of craft operating under poor visibility conditions. Still further, it would be an advance in the art to provide a system and method for tracking the position of a number of craft, for example a fleet of land craft which are carrying out tasks such as delivery of goods or people or other tasks.

BRIEF SUMMARY OF THE INVENTION

The present invention allows the position of a first craft to be monitored at a location remote from the craft. The position of the craft can be monitored at a stationary receiver or from on board another craft. Since a craft equipped with the present invention can monitor the position of other properly equipped craft, collisions therebetween can be avoided.

In the case where the present invention is fully implemented, i.e., all the craft in a fleet are equipped with embodiments of the present invention, all the craft are able to monitor the position of all other craft within a predetermined range. Moreover, each craft is able to accurately transmit its own position so the present invention is a great aid to navigation.

The present invention includes means, on board a first craft, for receiving or determining the position fix of the first craft. Any number of position-determining devices may be used. For example, the position of the first craft may be obtained by using an altimeter or depth finder, the widely accepted LORAN navigation system, or GPS position determining techniques.

The position of the first craft is encoded, preferably as a digital signal, so that the position information of the first craft can be carried by a radio frequency signal. Preferably, both the craft position fix, craft identification code, and other relevant information such as radio

frequency number, directory advisories, and equipment error flags are encoded so they can be carried by the radio frequency signal.

A large number of craft often operate within a limited range and may all transmit position information on the same radio frequency. In order to avoid interference with conflicting radio frequency signals, it is preferred that conflicting signals are listened for prior to transmitting the radio frequency signal.

Importantly, the present invention does not require interrogation by a land-based, or other transmitter before position information will be transmitted by a craft. The radio frequency signal carrying the position information, and preferably other messages and identification information, is regularly transmitted on a continuous basis.

The radio frequency signal which is transmitted (carrying at least the position information for the craft) is received by another craft or a stationary monitoring receiver at a remote location. The received radio frequency signal is decoded to extract the craft position, identification and other information therefrom. Using the position information, the position of the other craft is displayed.

If the radio frequency signal is received on board another craft, the position of the first craft is of great help to the operators of that craft to navigate, communicate and especially to avoid possible collisions. In order to aid the operators of that craft, the relative positions of each craft are also determined and preferably displayed.

By displaying the positions of the two craft as the craft move, a heading for each of the craft can be derived and displayed and the possibility of a collision assessed. In accordance with the present invention, if a collision is

possible between two craft on their present headings the operators of each craft are alerted so appropriate action can be taken. It will be appreciated that the greatest benefit from the present invention accrues when all craft have an embodiment of the present invention on board. When all the craft are so equipped, all of the craft can monitor the position of all other craft which are within a predetermined range.

Importantly, the present invention has applications other than providing collision avoidance advice. The present invention may be used as a navigational aid, for example, by automatically displaying the craft's position on a terrain map or graphically showing a landing approach. Moreover, with appropriate navigation information, the present invention may be implemented economically and some embodiments of the invention may be used anywhere in the world. Also, the embodiments of the present invention can be used to locate and direct precision emergency location and rescue efforts in the case of disabled craft.

Significantly, the present invention does not rely on interrogation by other craft to transmit its position fix. Rather, the radio frequency signal carrying the position information is transmitted regardless of the presence of any other craft or monitoring receiver. The strength of the radio frequency signal is limited so that it is received only within a predetermined range which is of interest. For example, the predetermined range of the radio frequency signal may be five, ten, thirty, or more miles. Moreover, rather than requiring a sophisticated radio direction finding antenna, the radio frequency signal of the present invention is preferably transmitted omnidirectionally so that all craft within the predetermined range will be able to extract the position information therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the herein-recited and other advantages and objects of the invention are obtained can be appreciated, a more particular description of the invention briefly described above will be rendered by reference to a specific embodiment thereof which is illustrated in the appended drawings. Understanding that these drawings depict only a typical embodiment of the invention and are not therefore to be considered limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

Figures 1A-1B are high level flow charts describing the presently preferred steps carried out by the system described herein.

Figure 2 depicts three aircraft as an example of the operating environment of the described embodiment of the present invention.

Figure 3 is a block diagram showing the major functional components of the described embodiment.

Figures 4-1 through 4-11 provide a flow chart describing the steps carried out by the preferred embodiment of the apparatus of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made to the drawings wherein like structures will be provided with like reference designations.

1. General Discussion.

As discussed above, the widely promoted and available collision avoidance systems, particularly those available to the aviation industry, inherently have several drawbacks. A major drawback is the fact that the cost of

installing the necessary on board equipment may exceed the cost of an entire small aircraft. Thus, economic consideration prevents such systems as TCAS, from being adopted by the great majority of the general aviation industry.

Moreover, TCAS equipment requires complex on board computers in conjunction with radio direction finding equipment. Since TCAS equipped aircraft are capable of interrogating all other aircraft in close proximity, the result is that a large number of interrogations will occur in high density air space. Eventually, the radio transmission media will become saturated thereby rendering both TCAS and secondary surveillance radar inoperative.

Even when working optimally, the TCAS and other collision avoidance systems provide only a transponder code assignment for identification, gives only relative heading information and if properly equipped, altitude information. In addition, the entire system is interrogation dependent.

In contrast to the previously available collision avoidance systems, the present invention makes use of existing ground based or satellite based equipment which has already been widely accepted, rather than requiring new dedicated equipment. Moreover, the present invention provides navigational aid and emergency location functions not contemplated in previously available systems. Importantly, the collision avoidance, navigation aid, and emergency location functions are all provided economically and thus the necessary equipment can be installed on board even small privately owned aircraft. Still further, the present invention can be applied in space, air, land, and sea craft and provide collision avoidance, navigation, and emergency location functions in nearly every environment, including IFR conditions.

The present invention is able to achieve its great advantages over the previously available systems by utilizing one of the existing position determining systems, or their equivalent, that is now available or currently being implemented. For example, using the LORAN system a craft, or in the case of portable LORAN receivers an individual, can immediately obtain a position fix measured in latitude and longitude, in many areas of the world. Also, the GPS scheme, when fully implemented, will allow a position fix measured in latitude, longitude, and altitude, to be determined anywhere in the world with great precision. These existing position determining systems, and others when available, are used by the present invention to provide advantages not heretofore available in the art.

The described presently preferred embodiment of the invention utilizes the LORAN position determining system. While one form or another of the LORAN system has been known for many years, especially in the marine environment, it has recently gained world-wide acceptance among other types of craft operators, and particularly among aircraft operators. The LORAN system provides more useful navigational information than many other navigational instruments now in popular use, especially in the aviation environment. It has proven to be a highly reliable and safe system and has even been conditionally approved by the FAA for non-precision approaches to approved landing strips.

The precision of the LORAN system generally ranges from 60 to 600 feet depending on the location of the craft in relation to the geometry of several widely spaced low frequency radio transmitters which provide the necessary position fixing signals. Because of the precision and versatility of the LORAN system, LORAN receivers are

available which include computers, databases and displays providing mapping and navigational aids to the operator of a craft as the craft travels. For example, LORAN equipment intended for aviation use is often provided with databases that are updated monthly to provide all current airport frequencies, runway orientation and length, airport elevations, VOR, restricted and prohibited flight areas, and other useful information.

Furthermore, some aviation LORAN receivers are able to immediately locate several of the nearest airports in times of emergency. LORAN equipment installed on aircraft is able to compute ground speed, wind direction and speed, tracking error, offer tracking and vertical navigation advisories, and report minimum safe altitudes and degrees of magnetic variation.

Excellent LORAN coverage is now available throughout most of North America. LORAN coverage is partially available in most other areas of the world including the North Atlantic, the United Kingdom, Europe, the Mediterranean Sea, North Africa, the Persian Gulf, Saudi Arabia, and Japan. The relatively low cost and high benefits of installing LORAN transmitters make the LORAN system attractive to governments of both industrialized and developing nations. Furthermore, upon its full implementation, the GPS scheme will provide even greater benefits. Since an existing position determining system is not available everywhere, the term "operational range" will be used to denote when a craft is in an area in which an existing position determining system can be effectively used.

Complete information concerning the LORAN system can be obtained from the publications Melton, L., The Complete Loran-C Handbook (Marine Publishing Co. 1986) and Sweeny, D. J., "Learning About Loran," Radio-Electronics Magazine

50-58, 69 (May 1987). Likewise, the GPS scheme may also be used in accordance with the present invention. Further information concerning GPS can be obtained from the publications entitled "Introduction to Global Positioning," Civil Engineering 16-20 (Jan./Feb. 1987), Ashjaee, J., "Global Positioning System: Refined Processing for Better Accuracy," Sea Technology 20, 22-25 (March 1986) and Enge, P. K. et al. "Differential Operation of the Global Positioning System," 26 IEEE Communications Magazine 48-60 (July 1988).

It will be appreciated that the present invention has application in many different circumstances. Thus, as used herein the term "craft" is intended to include any stationary object, any mobile animal or person, or any mobile apparatus or vehicle. For example, land, sea and air craft are specifically intended to fall within the meaning of the term "craft."

Also, as used herein, the term "monitoring receiver" means any device or apparatus invention which can monitor the position of a craft which is transmitting position information in accordance with the present invention.

The present invention comprises an apparatus and method for announcing the position of a craft to a monitoring receiver, either stationary or mobile, remotely located from the craft. In one application, the present invention can be used to track the position of one or more craft at a stationary receiver. In another application, the present invention can be used by one craft to track one or more other craft. With the present invention in place, as a first craft tracks all the other craft positioned within a predetermined range of the first craft, and the operator of the first craft is apprised of the position of all the other craft, collisions between the craft can be avoided.

The presently preferred embodiment of the invention which is described herein is intended to be used primarily in the aviation industry. Those familiar with the aviation industry will appreciate that the problems of collision avoidance are particularly troublesome in today's crowded airspace. Adding to the problem of collision avoidance in the aviation industry are: the limited operator's field of vision in an aircraft cockpit; the speeds of the craft on a collision course provide very little time for a pilot to react and take corrective action; and an aircraft on a collision course may come from any direction in space.

Also a universally useable or mandated collision avoidance system must be economically feasible for both small, modestly priced aircraft carrying just one or two persons and large multi-million dollar aircraft carrying hundreds of passengers and/or freight. Thus, at the current time, a most urgent need for the present invention lies within the aviation industry.

Nevertheless, the present invention can be used as a position announcing and/or collision avoidance system in other demanding situations such as with water craft. Also, the present invention can be applied where a dispatcher needs to track the movement of a plurality of vehicles in a fleet, for example, motor trucks as their movements are coordinated for making deliveries and/or pickups, buses, trains, construction and other land based equipment.

2. Detailed Description in Reference to Figures 1-4.

In order to describe the presently understood best mode for making and using the present invention, the presently preferred embodiment of the present invention, as intended to be used in an aircraft environment will be described. As will be appreciated, the application of the present invention to air traffic monitoring and collision

avoidance is one of, if not the most, demanding of the contemplated applications of the present invention because of, among other things, the speeds of the craft involved and the desirability to monitor three dimensional space as opposed to two dimensional space in the case of water and land craft.

Referring now to Figures 1A-1B, the preferred general method used by the system of the present invention will be explained.

As shown at 10 in Figure 1A, the initial step of the transmit loop 9 is to obtain a position fix for one's own craft, also sometimes referred to herein as a first craft. The position fix is obtained using apparatus on board the craft. It is preferred that the position fix be obtained using an existing automated navigational system which will provide the position of the craft relative to a fixed reference, for example, latitude and longitude. This arrangement is in contrast to other collision avoidance systems which merely determine the distance between two craft and not their position relative to a fixed reference system. The LORAN system and the GPS system are among the preferred existing external automated navigational systems.

While navigational systems which are capable of providing a position fix in two dimensions (e.g., LORAN) or three dimensions (e.g., LORAN in combination with an altitude encoder or GPS) are preferred, in some applications of the present invention it may only be necessary to obtain a position fix in one dimension or plane of space. For example, in one application of the present invention, an operator of an aircraft may only need to know if another craft is operating at the same altitude. While such information is only a portion of that which the described embodiment of the present invention can provide, it is of use to alert the operator of an aircraft. If

another aircraft is operating within a close range at the same altitude, an operator of the aircraft should be warned that a collision with a another aircraft is possible if precautions are not taken.

Thus, the position fix can be obtained from an altimeter only (for a one dimensional position fix), from a LORAN receiver (for a two dimensional position fix), from both a LORAN receiver and an altimeter or a GPS device (for a three dimensional position fix). Other devices can also be used to obtain a position fix.

As indicated at step 12 in Figure 1, the position fix which was obtained in step 10 is encoded so that it can be carried by a radio frequency signal. In addition to the position fix, an identification code (such as an aircraft registration number) and/or other messages are also encoded. It is preferred that the position fix and the identification code and other messages be digitally encoded so that they can be transmitted at a relatively high baud rate as will be described in detail below.

In the United States, the radio frequency allocation of 1.6 Gigahertz has been reserved for aviation use. Thus, it is presently preferred, but not required, to utilize the 1.6 Gigahertz frequency allocation. Since all aircraft utilizing the present invention preferably utilize the same frequency, step 14 provides that any conflicting radio frequency signals are listened for.

One of the significant advantages of the present invention is that, as opposed to previously available collision avoidance systems, a craft transmits its own position fix and identification code information without being interrogated.

Since many craft may be using the described embodiment of the present invention, all using just one or a few radio frequency allocations, avoidance of conflicting radio

frequency signals is necessary. In use, some conflicts may occur in the described embodiment in areas where craft are highly concentrated. In the described embodiment, the position fix and identification code information is regularly and repeatedly transmitted. Thus, if an attempt at transmitting the position fix and identification code is postponed or "walked on" by another transmission, the information will be repeated in a short period of time.

One preferred arrangement for preventing interference between conflicting radio frequency signals is to first listen for conflicting signals, as at step 14, and if a conflicting signal has existed, then wait a random period of time after the detection of a conflicting radio frequency signal, as at step 15. The length of the random period of time can be, for example, derived from the registration number of the aircraft, a random generation, or some other means. Alternatively, after the detection of a conflicting radio frequency signal, a predetermined period of time may be waited before transmission.

Additional details concerning the settlement of a conflict between radio frequency signals can be devised by those skilled in the art and further information concerning the preferred example is provided later in this disclosure. It will be understood that various schemes, including the use of scanned multiple frequencies (speed spectrum technology), higher transmission rates, and other non-interrogation schemes, can be devised and used with the present invention.

At step 16 in Figure 1, the radio frequency signal carrying the position fix and identification code information is transmitted and the pilot's own craft and relative bearing are displayed at step 17. The system then waits at step 19 for the transmit timer to expire, before re-entering the loop for another transmission.

Whether it is desired to avoid collisions between multiple craft or to track a single craft, it is nearly always desirable to have the radio frequency signal received only within a limited range. Thus, the radio frequency signal is of limited strength. For example, when functioning to avoid collisions between aircraft, the area of interest is generally a radius of between from about 1 to about 30 miles around one's own aircraft or around the airport. Nevertheless, in some cases, such as in the case of land or sea craft, the range of interest may be greater or lesser than that which is desirable for aircraft.

The radio frequency signal carrying the position fix, identification code information, and other messages, is of limited power so that only the radio frequency signal transmitted from craft within a predetermined range will be received. This reduces the number of radio frequency signals which conflict with one another, allowing a large number of aircraft to be simultaneously operating within a predetermined range. Other embodiments of the present invention can be fabricated which allow a greater number of craft to be simultaneously operating within the predetermined range.

Preferably, the radio frequency signal from each of the aircraft is transmitted, and received, omnidirectionally. Since position information is encoded within the radio frequency signal, and not derived from the signal strength or direction, complicated antenna arrangements are not necessary with the present invention. As will be appreciated, in the case of aircraft the term "omnidirectionally" is intended to include three planes of space while in the case of land or water craft, the term "omnidirectionally" generally need only include horizontal two dimensional planes surrounding the craft.

As indicated at step 18 of receive loop 13 in Figure 1B, the radio frequency signals for other craft are transmitted and are received at a craft or another location which is equipped with a monitoring receiver in accordance with the present invention. The receiving location may be a ground location which is tracking one or more craft. The radio frequency signals are decoded, as indicated at step 20, and the position fix and identification code information is displayed at step 21.

Once the position information has been extracted from the radio frequency signals, the position of all the other craft within the predetermined range can be displayed as represented at step 21 in Figure 1B. As each craft regularly transmits its own position, it is possible to calculate all relative essential elements of heading, speed and distance of each craft which can then be displayed. In the case of craft on a collision course, the projected point of impact and time of impact can be calculated and displayed while the operators of the craft are alerted to the danger and given appropriate advisories. While it is not always necessary, it is preferred that an identification code for each craft be transmitted. The transmission of a craft identification code and its current operating communication radio frequency simplifies the organization of incoming data and enhances safety by providing a craft identification for two-way radio communication.

Included in step 21 of displaying the position of all craft transmitting a radio frequency signal within the predetermined range is preferably the step of displaying the position of one's own craft. Also, it is preferable to issue a collision alert if a collision is possible between two craft on their present headings. Also, since, one's own position fix has already been determined, it is pos-

sible to display the position of one's own craft against a map superimposed on the display. Data to create such maps can be provided by databases as are available in the art.

Preferably, each of the craft may be provided with a recording device which will provide a non-volatile record of all position and identification information which is received, and if desired the position information of one's own craft. Thus, if an aircraft were to become disabled and go down, the radio frequency transmissions would continue to transmit the position and identification of the craft to be observed by other craft. If the apparatus did not survive a crash, any properly equipped craft within range recording all received position and identification information and the last transmitted radio frequency signal from the downed aircraft would provide precise information of the location information of the crash site. With either alternative, the present invention can be used as an emergency location system that will supply more precise information than that commonly available on the ELT (Emergency Location Transmitter) system in current use.

Referring next to Figure 2, a primary aircraft 30 is represented at the center of a sphere 36. The sphere (which is not to scale) represents the predetermined range in which the radio frequency signal broadcast from the primary aircraft 30 can be received by other aircraft also carrying the system of the present invention. Thus, the operator of a secondary aircraft 32, being within the predetermined range, will receive a collision alert if the two craft are on a collision course. Alternatively, another secondary craft 34 will not be made aware of the position of the other two aircraft until it comes within the predetermined range represented by sphere 36. A ground based monitoring receiver 38 is also represented in Figure 2. The ground based monitoring receiver can function as an

air traffic control station as the craft come within range.

Referring next to Figure 3, a block diagram of the presently preferred embodiment of the present invention is provided. The high level functional blocks include: a position determining block 100; an interface controller block 102; a radio frequency block 104; an antenna 106; and a control block 108. In most of the functional blocks, additional components are represented. The components represented in Figure 3 are generally included on board a craft or can be located at a stationary location.

Represented within the position determining block 100 are a latitude/longitude position determining device 100A and an altitude determining device 100B. It will be appreciated that many aircraft already include appropriate latitude/longitude position determining devices and an altitude determining device and thus the components represented within the position determining block 100 may not be included in all embodiments of the present invention. It is one of the advantages of the present invention that the existing equipment already provided on many aircraft can be used in conjunction with embodiments of the present invention. In the case of a water or land craft, the inclusion of only a latitude/longitude device is generally all that is necessary.

The presently preferred latitude/longitude position determining device is a LORAN-C receiver available from ARNAV, a subsidiary of Flight Dynamics, Inc., of Portland, Oregon and referred to as Model R-50. The described LORAN receiver provides many desirable features as well as the ability to communicate with other devices via the industry standard RS-232 communication protocol.

The presently preferred altitude determining device is an altimeter available from ACK Technologies, Inc. of San Jose, California, Model A-30. Information concerning

interfacing the indicated altimeter to other components is available from the manufacturer.

The devices included in the position determining block 100 are a preferred example of a means for determining, on board a craft, the craft's position using an existing external navigation system. The means for determining the craft's position can include, depending upon the particular application of the invention, devices for determining the craft's position in one, two, or three dimensions (or planes) of space.

The present invention includes means for encoding the position of the craft, which can also preferably encode an identification code for the craft, so such information can be carried by a radio frequency signal. The presently preferred example of a means for encoding the position and identification of the craft is the interface controller 102 represented in Figure 3.

The identification code may be an aircraft registration number or any other number unique to the craft. While it is not essential to encode and transmit the craft identification code with the radio frequency signal, it is desirable to do so.

Still referring to Figure 3, the interface controller 102 communicates with the devices of the position determining block 100 by way of communication ports included in the devices. The presently preferred example of the interface controller 102 is a system available from Enduratek Corporation of Salt Lake City, Utah and referred to as the Data-V-Com system. Complete information concerning the Data-V-Com system can be obtained from the publication "Mobile Data Terminal System Operations Manual" available from Enduratek Corporation.

The interface controller 102 system performs data encoding and preparation functions needed to transmit the

digital information via a radio frequency signal and functions as the presently preferred example of a means for encoding the position of the craft into information which can be carried by a first radio frequency signal and a means for decoding the other craft's position from a radio frequency signal. Other devices performing similar or equivalent functions are intended to be included within the scope of the means for encoding included within the present invention. The designated interface controller 102 also functions as the presently preferred example of a means for decoding the position and identification information received from other craft.

The radio frequency block 104 includes a modulator 104A, a radio transmitter 104B, an antenna duplexer 104C, a radio receiver 104D, and a demodulator 104E. The components of the radio frequency block are preferably included in a radio frequency transceiver capable of operating in the microwave band containing 1.6 Gigahertz. One presently preferred transceiver which operates in the VHF band is available from Icom, Model No. IC-A20. It will be appreciated that devices other than the designated transceiver, and frequencies other than 1.6 Gigahertz, for example any appropriate radio frequency may be used within the scope of the present invention.

Also represented in Figure 3 is an antenna 106, which may comprise one or more individual antennas or antenna elements, and which is preferably one that will provide an omnidirectional radiation pattern. It is desirable that the radiation pattern and the reception pattern both be omnidirectional. The antenna duplexer 104C serves to isolate the radio transmitter 104B from the radio receiver 104D while allowing both to use the same antenna.

Still referring to Figure 3, a modulator 104A functions to modulate the carrier radio frequency wave with

the craft position and identification information encoded by the interface controller 102. A demodulator 104E similarly functions to extract the position and identification information from any radio frequency signal which is received and to pass the same onto the interface controller 102. The modulator 104A and demodulator 104E may be embodied in a device commonly referred to as a modem, which is available in the art.

The components represented within the radio block 104 and the antenna 106 are the presently preferred example of a means for transmitting the first radio frequency signal and a means for receiving a radio frequency signal. The interface controller 102 communicates with, and operates, the components of the radio frequency block 104 by way of connectors and cables customarily included on radio frequency transceivers as will be understood by those skilled in the pertinent art.

The interface controller 102 represented in Figure 3 also communicates with a computer 108A which is included in the components of the control block 108. The computer 108 is preferably one which is equivalent to an IBM model PC AT. One of the many commercially available portable models (generally referred to as "Lap Tops") of the specified equivalent computer can also be used. The computer 108A and the interface controller 102 communicate with each other by way of the customary connectors and protocols (such as the RS-232 protocol) which are well known to those skilled in the art.

Included in the control block 108 is a display 108B. The display 108B may be integral with the computer 108A or may be separate therefrom. The display is preferably used to provide a graphical representation of the position of the craft which are within the predetermined range of the monitoring craft or receiver.

Thus, the operator of the craft can observe on the display the position of both his own craft (desirably in the center of the display) and the position of all other craft surrounding his craft within the predetermined range.

One preferred embodiment of the display would incorporate the use of a head-up display to display not only collision avoidance information, but to also aid in proximity reporting, navigation under IFR conditions, coordinated descence into controlled and uncontrolled airports and landing strips, and other relevant information, and to project these pertinent images in a forward view mode into the wind screen and line of the actual and preferred flight path.

It will be appreciated that some embodiments of the present invention may provide additional benefits if the display is one which not only provides high resolution in two dimensions, but one which is also suitable for displaying three dimensions, i.e., a display wherein depth can be represented by either using a three dimensional graphics mode or by decreasing intensity as a position recedes from the viewer and greater intensity as the position moves toward the viewer. Altitude information as well as indicators showing whether or not aircraft are climbing or descending can also be depicted on the display.

In the case of the present invention as applied to the aviation industry, it is desirable that the position of aircraft other than those in the same horizontal plane be displayed. Namely, the display 108B should provide position information of a plurality aircraft vertically displaced from the monitoring craft (i.e., differing altitude) as well as in the same horizontal plane (latitude and longitude). Depending upon the particular embodiment of the invention, the display 108B , or all of the components represented in radio block 108, function as a

means for displaying a craft's position as defined by the present invention. Other devices and arrangements performing similar or identical functions are intended to be considered equivalent to the described structures.

Also represented in the control block 108 are input devices 108C. Input devices 108C can include a keyboard (which may be integral with the computer 108A) or other general purpose or dedicated input devices. An audio/visual alarm 108D is also represented in control block 108. The audio/visual alarm can be integral with the computer 108A or can be one of several dedicated alarm devices intended to apprise the operator of a craft of a potential collision or other situation requiring attention.

A recorder 108E is also provided in the control block 108 to make a non-volatile recording of selected data received by the computer 108A. Preferably, the recorder 108E is used to periodically log the position of all craft within the predetermined range. Thus, if a monitored craft becomes disabled and stops transmitting its radio frequency signal carrying position information, the last recorded position fix logged in the recorder 108E of any craft or observation station within the predetermined range can aid in the location of a disabled craft.

Furthermore, if a craft continues to transmit its radio frequency signal with its own position fix after becoming disabled, it will function as an emergency location device and will assist search and rescue crews in the rapid location of the disabled craft. In some embodiments of the invention, the radio frequency signal can carry, in addition to position and identification information, a distress signal as well as other messages to indicate a need for emergency assistance and even describe what type of emergency assistance is required at the disabled craft.

If desired, the components of the control block 108, the interface block 102, and the reception components of the radio frequency block 104 can be used as a monitoring receiver. For example, a monitoring receiver can be used as a ground control station to monitor the airspace surrounding an airport. In the case of small airstrips or airports in developing areas, the present invention can be adapted to provide both airborne craft and ground control personnel the information necessary to coordinate air traffic. This application of the embodiment of the invention would allow for the system's use as a standard ATC system exclusive of expensive radar installations, and at extremely low cost.

It will be appreciated that while the described embodiment is the presently best known mode for carrying out the invention, those skilled in the pertinent art will understand that other components may be used to carry out the invention. For example, the functional blocks illustrated in Figure 3 may be combined into a few, or just one, devices housed in a single enclosure. Moreover, as the art progresses, the inventive concepts of the present invention may be embodied in devices not yet available but carrying out functions equivalent to those described in connection with the preferred embodiment. All such alternative embodiments of the invention are intended to fall within the scope of the present invention.

Provided in Figures 4-1 through 4-11 is a more detailed flow chart describing the steps carried out by the above-described embodiment. In these figures, the boxed letter designations indicate the interconnections between the portions of the flow chart which are divided between figures.

The flow chart provides a description of the high-level functions carried out principally by the interface

controller 102 represented in Figure 3. In the presently preferred embodiment of the present invention, the interface controller 102 is implemented by the above described Data-V-Com system.

It will be appreciated that the flow chart represented in Figures 4-1 through 4-11 represents just one preferred example of the programming steps that can be used to carry out the present invention and those skilled in the art will be able to devise other embodiments of the present invention using the teaching contained herein. Also, as will be appreciated after an examination of Figures 4-1 through 4-11, the Lap Top (a portable computer which functions as the computer 108A represented in Figure 3) functions principally to display the data presented to it by other components and to provide input and output functions with a human user. The text contained in the dashed boxes are included to improve the clarity of the flow chart and do not represent steps in the method.

The flow chart contained in Figures 4-1 through 4-11 is divided into several principal routines as indicated below.

Flow Chart Routine	Figure Nos.
Initialization	Figs. 4-1 through 4-4
Radio	Figs. 4-5 though 4-6
Loran	Fig. 4-7
Altimeter	Fig. 4-8
Lap Top	Figs. 4-9 through 4-11

Further information concerning each of the routines indicated above is provided in the Glossaries set forth below.

A. Initialization Routine Glossary.

Ref. No.	Label	Description
200	START	This is the beginning of the program. When the micro-processor is reset via hardware or software it is vectored to this point. At START, the Stack Pointers, Interrupt disabling and various other Housekeeping chores are performed.
202	SELFTEST	This is the beginning of the Selftest Module. At this point the Diagnostic Terminal will display that Selftest has started. Also at this point Selftest Interrupts will be set up and enabled.
206	RAM TEST PASS	The RAM (Random Access Memory) test is run. The RAM test writes data found in a ROM table to each RAM address. If the same data that was written is read back, the program continues through the table until the data 00H is written. This signifies the end of the test and leaves all RAM cleared and ready for use. If the test fails at any point the data read, data written and the address are saved and reported back to the Diagnostic Terminal. The RAM should be replaced at the address reported if failure occurs.
208	SET RAM TEST FAIL BIT	The Selftest Status is sent to the Lap Top and to other Aircraft via the Radio. If this bit is set it means that the RAM Test Failed and all data is unreliable.
210	ROM TEST PASS	All Used ROM (Read Only Memory) is added and the sum must equal zero. The Check Sum Adjust Byte at 3FFFH ensures that the sum (without carry) is zero. If the sum is not zero the test fails and ROM should be replaced. The test failure status and the erroneous check sum are reported to the Diagnostic Terminal.

212	SET ROM TEST FAIL BIT	The Selftest Status is sent to the Lap Top and to other Aircraft via the Radio. If this bit is set it means that the ROM Test Failed and all data is unreliable.
214	LAP TOP INTER. PASS	The USART (Universal Synchronous Asynchronous Receive Transmit) 8051 is Software reset and the MIF (Mode Instruction Format) set up. Status is then checked and verified.
216	SET LAP TOP INTERFACE FAIL BIT	The Selftest Status is sent to the Lap Top and to other Aircraft via the Radio. If this bit is set it means that the Lap Top Communication could be unreliable.
218	I/O TEST PASS	The PIA (Peripheral Interface Adapter) 8155 is initialized for the proper mode, which ports are Inputs and which are outputs and the Baud rate Clock set up. Outputs are initialized. Status is then checked and verified.
220	SET INPUT/OUTPUT FAIL BIT	The Selftest Status is sent to the Lap Top and to other Aircraft via the Radio. If this bit is set it means that the PIA is unreliable. The PIA interfaces mainly with the Altimeter.
222	RADIO INTER PASS	The USART (Universal Synchronous Asynchronous Receive Transmit) 8051 is Software reset and the MIF (Mode Instruction Format) set up. Status is then checked and verified.
224	SET RADIO INTERFACE FAIL BIT	The Selftest Status is sent to the Lap Top and to other Aircraft via the Radio. If this bit is set it means that the Radio Communication could be unreliable.

226	ADD AIRCRAFT ID	Each System has its own Aircraft Identification Via the Diagnostic Terminal the Aircraft Identification is put in NonVolatile Memory or EEPROM. (Electrically Erasable Read Only Memory). This Identification number will not be lost if the system is reset or powered down. When Selftest is run the system can sense that the Terminal is attached and allow the user the option of changing the Aircraft Identification This block asks the question, Do You Want to Enter Aircraft Identification?
228	GET AIRCRAFT ID	This block Prompts the Terminal, for the Identification, Error Checks it and buffers it.
230	ENTER AIRCRAFT ID	This block enters the buffered aircraft Identification into EEPROM.
232	PUT IN RANDOM XMIT TIMER	Because the preferred embodiment of the present invention is polite (will not transmit when another signal is already present on the frequency). To eliminate various systems transmitting simultaneously, each system will have different wait times before transmitting after a frequency has cleared. This random wait time is determined by the system Aircraft Identification in the preferred embodiment.
234	TOGGLE PRINTER STAT.	Changes the printer status.
236	CHG PRINTER STAT	To enable someone to monitor the entire system there is a port for a printer or some other type of monitor. At this time the Diagnostic Terminal can be used for changing the Status of the Printer or Monitor. The Status is kept in NonVolatile ROM or EEPROM so that if the System is powered down or reset that status will not change.
240	INITIA-	Pointers such as the Input and Output

	LIZE POINTERS TIMERS ETC.	Pointers for the Rotating buffers used for the Lap Top Interface are set up at this time.
242	SET ALTIMETER DATA TO 9's	At this point in the Program it is not known if the Altimeter is functional or not, especially since the Altimeter does not function for several minutes after it is powered up. So that any data present is not mistaken for good Altimeter Data all 9's are inserted in the Altimeter use area.
244	SET LORAN DATA TO 9's	At this point in the Program it is not known if the Loran Receiver is functional or not, especially since the Loran Receiver must be initialized manually to send the proper information at the proper baud rate, transmit rate, and so forth. To ensure that any random data already present is not mistaken for good data, all 9's are inserted in the Loran Longitude and ~~Latitude buffers.~~
246	SET # MESSAGE FLAG	The # message Flag is set so that when the system is fully initialized and functional, the # message will be sent to the Lap Top Computer.
250	EXECLP	This is the exit point for initialization that has been performed heretofore and the loop point for the rest of the program. When the rest of the program has completed it will come back to this point and begin again at this point.
252	CALL RADIO	The Radio Module (See step 276, Figure 4-5) is interfaced at this point.
256	CALL LORAN	The Loran Module (See step 312, Figure 4-7) is interfaced at this point.
260	CALL LAP TOP	The Lap Top Computer Module (See step 348, Figure 4-9) is interfaced at this point.

264	RESET WATCH DOG	See step 266.
266	TRANSMITTING	If the system is transmitting the watch dog timer is not reset. This helps to ensure that the system does not transmit for too long a period. If the watch dog is not reset every 1.1 seconds the system is reset, the Program Counter goes to 0000H or the Start.
268	CALL ALTIMETER	The Altimeter Module is interfaced at this point.

B. Radio Routine Glossary.

Ref. No.	Label	Description
272	RANDOM TIMER EXP	After the frequency has been busy this timer must expire before transmitting. (See steps 232 (Figure 4-2) and 278 (Figure 4-5).
274	'T' RELOAD VALUE NON 0?	
276	RADIO	This is the entrance to the RADIO module. This module handles all the communication to/from the Radio. All communication to other aircraft is via the Radio.
278	RESET XMIT TIMER	The value used to reset the XMIT timer is the value obtained from the 'T' message from the Lap Top Computer. (See steps 274 (Figure 4-5), 350 (Figure 4-9) & 376 (Figure 4-10).
280	CHANNEL CLEAR	Because the system is polite (See step 232 (Figure 4-2)). It will not transmit unless the channel is clear. The Carrier Active Sense (CAS) is checked at this point to see if the frequency is clear or not.

282	XMIT TIMER EXP	The location message for this aircraft must be transmitted to the other aircraft at a rate determined via a 'T' message from the Lap Top Computer. If the 'T' message time is 0 then (which is what it is upon initialization) then the message is not transmitted at all.
286	GET THIS AIRCRAFT ID	The Aircraft Identification is read from EEPROM and stored in the Radio Transmit buffer. (See steps 230, 228 (Figure 4-2), & 226).
290	RESET RANDOM TIMER	The Random timer must be reset with the value determined from the Aircraft Identification (See steps 232 (Figure 4-2), 280 & 372 (Figure 4-5).
292	GET LORAN LAT. LON. DATA	The most recent data from the Loran Receiver is placed in the Transmit buffer. (See steps 292 (Figure 4-6), 314 & 320 (Figure 4-7)).
296	MESSAGE RECEIVED?	By examining the input buffer it can be determined if a message has been received.
298	CHECK SUM CORRECT	Each byte of the message is added w/carry and it is determined if the message is error free or not.
300	PUT MESSAGE IN LAP TOP BUFFER	The message received above is rebuffered into the large rotating Lap Top Computer Buffer for transmittal to the Lap Top Computer.
302	GET LORAN STATUS	This byte indicates the Loran Status. (See step 330 (Figure 4-7)). The Loran Receiver transmits in addition to the Latitude and Longitude the Status of the Receiver.
304	SET LAPTOP MESSAGE READY FLAG	This flag tells the Lap Top Module that a message is ready to go to the Lap Top Computer.

306	GET DATA V-COM STATUS	The Data-V-Com Status includes not only the Selftest status, (See steps 208, 212, 216, 220 & 224 (Figures 4-1 & 4-2)) but also status as to how current the Loran Information is.
308	GET MESSAGE CHECKSUM	After concluding with step 306 (Figure 4-6) the message is formatted and the Check sum is calculated by adding up each byte (w/carry).
310	OUTPUT MESSAGE	The message formatted above is output (AFSK) via the USART. An attack delay (a period of no data to enable the transmitter to stabilize) as well as a time delay at the end is necessary.

C. Loran Routine Glossary.

Ref. No.	Label	Description
312	LORAN	This is the Entrance Point for the Loran Module. This module handles the interface with the Loran receiver. Besides receiving the Latitude and Longitude it also saves the Loran Status and keeps track of if an update occurs between Message transmissions to other aircraft and to the Lap Top.
314	SAVE LATITUDE	The Latitude less the spaces is saved. (See step 318 (Figure 4-7)). A flag is set so that it can be determined that data was received for Lat. and Lon. so that when processed will be data that is compatible.
316	LATITUDE	Checks for LAT (See step 318 (Figure 4-7)) in message coming in from Loran Receiver.
318	MESSAGE COMING IN?	The entire message from the Loran Receiver is not saved. If a message is coming in the program looks for LAT for Latitude and LON for longitude and SD for Loran Status. If these labels are found the data less the spaces is saved.

320	SAVE STATUS	The Loran Status is saved for transmission to other Aircraft, as well as the Lap Top Computer. This makes it possible to know the accuracy of the Loran as well as other pertinent information. (See steps 388 (Figure 4-11) & 302 (Figure 4-6)).
322	LONGITUDE ?	Checks for LON (See step 318 (Figure 4-7)) in message coming in from Loran Receiver.
324	ALL DATA RECEIVED?	See step 318.
326	PUT LAT. IN LAPTOP BUFFER	The message received above is rebuffered into the large rotating Lap Top Computer Buffer for transmittal to the Lap Top Computer.
330	SAVE STATUS	See step 320.
332	LORAN STATUS?	A flag is set for each of the 11 different types of status if that particular status is read from the Loran Receiver.
334	PUT LON. IN LAPTOP BUFFER	See step 326.
336	PUT LORAN STATUS IN LAPTOP BUFFER	See step 332.

D. Altimeter Routine Glossary.

Ref. No.	Label	Description
338	ALTIMETER	This is the Entrance point to the Altimeter handler. It reads the 11 Discrete inputs and decodes the data to an ASCII altitude. If the altitude is bad a 998 is output.

340	GET DISCRETE INPUTS (11)	Reads the 11 Discrete inputs from the Altimeter. If some are not used the program is modified so that they are assumed to be most significant and low.
342	GET ALT. FROM TABLE	The data is deemed good and saved for messages to the Lap Top and to other Aircraft.
344	INPUT DATA IN TABLE	A look up table is used to decode the 11 inputs to a three digit altitude reflecting 100's of feet. If the table reflects 998 then the data is deemed to be bad and is rejected.
346	GET '998'	The data in the table was bad, so instead of unreadable data a '998' is used to reflect the error.

E. Laptop Routine Glossary.

Ref. No.	Label	Description
348	LAPTOP	This is the input to the module. This module handles all communication to/from the Lap Top Computer.
350	PUT '#' IN MESSAGE	Put the '#' is the output buffer for this particular message to the Laptop.
352	CLEAR '#' FLAG	See step 354 (Figure 4-9).
354	'#' FLAG SET?	This flag indicates that a # Message must be sent to the Lap Top Computer. This flag is set only during Initialization. (See step 246 (Figure 4-3)).
358	GET THIS AIRCRAFT ID	The Aircraft Identification in Nonvolatile memory (EEPROM), is put in the transmit buffer to go to the Lap Top Computer. (See step 228 (Figure 4-2)).

360	GET MESSAGE FROM OTHER AIRCRAFT	The message that was received from another aircraft via. the RADIO module is rebuffered and sent to the Lap Top Computer.
362	'0' FLAG SET?	The '0' determines if messages from other Aircraft are accepted or not. If the Flag is set, which must occur when a '0' message is received from the Lap Top Computer, (See step 378 (Figure 4-10)) then other aircraft messages are accepted.
364	GET SELFTEST STATUS	The Selftest Status (See steps 208, 212, 216, 220 (Figure 4-1) & 224 (Figure 4-2)) is put in the buffer to be transmitted to the Lap Top Computer.
366	RESET 'L' TIMER	The time value received from the Lap Top Computer, (See step 390 (Figure 4-11)) is used to reset this timer.
368	'L' TIMER EXP	The 'L' timer determines how often the Location message for this aircraft is sent to the Lap Top Computer. If the value is set at 0, which occurs on initialization, it is not sent at all. The value that the 'L' timer is set to is determined by the 'L' message received from the Lap Top Computer. (See step 390 (Figure 4-11).
372	GET THIS AIRCRAFT ID	The Aircraft Identification in Nonvolatile memory (EEPROM), is put in the transmit buffer to go to the Lap Top Computer. (See step 228 (Figure 4-2)).
376	GET THIS LONGITUDE LATITUDE	This information is obtained from the Loran module. (See steps 314 & 320 (Figure 4-7)) and is put in the transmit buffer to go to the Lap Top Computer.
378	" 0 " MESSAGE?	Is the incoming message from the Lap Top Computer an '0' message? If so the '0' flag is set. (See step 362 (Figure 4-10)).

380	SET "0" FLAG	See step 378 (Figure 4-10).
382	GET THIS ALTITUDE	This information is obtained from the Altitude module. (See step 342 (Figure 4-8)) and is put in the transmit buffer to go to the Lap Top Computer.
384	" T " MESSAGE?	Is the incoming message from the Lap Top Computer a 'T' message? (See steps 274 & 282 (Figure 4-5)). If so the 'T' Reload value is saved. This value determines how often the Radio Transmits the Location of the Aircraft to other Aircraft.
386	GET "T" RELOAD VALUE	See step 384 (Figure 4-11). This value is used at step 372 (Figure 4-5).
388	GET THIS LORAN STATUS	This information is obtained from the Loran module. (See step 330 (Figure 4-7)) and is put in the transmit buffer to go to the Lap Top Computer.
390	" L " MESSAGE?	Is the incoming message from the Lap Top Computer an 'L' message? (See steps 368 (Figure 4-10) & 392 (Figure 4-11)). If so the 'L' Reload value is saved for use at step 366 (Figure 4-10).
392	GET "L" RELOAD VALUE	See step 390 (Figure 4-11). This value is used at step 366 (Figure 4-10).
394	GET CHECKSUM	After concluding with step 388 (Figure 4-11) the message is formatted and the Check sum is calculated by adding up each byte (w/carry).
396	" R " MESSAGE?	Is the incoming message from the Lap Top Computer an 'R' message? If so the program is vectored through software to the start address. (See step 276 (Figure 4-5)).
398	OUTPUT MESSAGE	The message formatted above is output via the USART to the Lap Top Computer.

3. Summary.

In view of the foregoing, it will be appreciated that the present invention provides a system and method for announcing the position of a craft to a remote receiver such that the position of the craft can be continuously monitored and collisions with other craft avoided. The present invention also provides a system and method for collision avoidance which may be used in addition to, and without interference with, preexisting collision avoidance systems.

It will be further appreciated that the present invention also provides an emergency location system for distressed or disabled craft and a collision avoidance system which can be economically implemented in the general aviation industry. Still further, the present invention provides a system and method which allows the operator of a first craft to monitor the position of a plurality of other craft within a predetermined range of the first craft and to be alerted of a potential collision as early as possible.

The present invention also provides a system and method of monitoring craft proximity spacing, a critical function, while operating within the flight sector system in high density areas and while transitting or making approaches in VFR and IFR controlled airspace. Further, the system and method provide a similar function in the marine environment, particularly under adverse weather conditions and high density mooring or docking maneuvers.

Even further, after consideration of the foregoing, it will be understood that the present invention provides a system and method for announcing the position of any craft to other craft which are within a predetermined range which is reliable and which does not distract an operator of a craft from other duties unless operator attention is

necessary. Moreover, the operator of a first craft is allowed to continually monitor the positions of a plurality of other craft within a predetermined range. Even further, the present invention provides a system and method of tracking the position of one or more craft within a predetermined range of a location anywhere on the earth such as at a remote airstrip or allows the position of each of a plurality of craft belonging to a fleet to be tracked. Still further, the present invention provides a collision avoidance system which does not become saturated in areas of dense traffic and which readily makes a permanent record of the movement of any craft within a predetermined range of a monitoring receiver.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiment is to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A method for announcing the position of a first aircraft at a first position, the first position being within airspace containing a plurality of other aircraft, to a receiver located at a second position not farther than a predetermined range from the first position, the method comprising the steps of:

(a) determining on board the first aircraft the position of the first aircraft relative to a fixed reference;

(b) encoding the position of the first aircraft so that the position of the first aircraft can be carried by a first radio frequency signal;

(c) avoiding conflicts with any radio frequency signals present in the airspace which conflict with the first radio frequency signal;

(d) transmitting the first radio frequency signal carrying the position of the first aircraft from the first aircraft;

(e) receiving the first radio frequency signal transmitted from the first aircraft at the second position;

(f) decoding the position of the first aircraft from the first radio frequency signal; and

(g) monitoring the position of the first aircraft within the airspace at the second position so that the position of the first aircraft within the airspace is known relative to the fixed reference.

2. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of determining the position of the first craft comprises the step of receiving a LORAN signal.

3. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of determining the position of the first craft comprises the step of receiving a GPS signal.

4. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the fixed reference exists both within the airspace and without the airspace.

5. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 4 wherein the step of determining the position of the first aircraft comprises the step of determining the position of the first aircraft in reference to the fixed reference.

6. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 5 wherein the step of determining the position of the first aircraft further comprises the step of determining the altitude of the first aircraft.

7. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 or 5 wherein the step of encoding the position of the first aircraft comprises the step of encoding the position of the aircraft into a digital pulse train.

8. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 7 wherein the step of encoding the position of the first aircraft further comprises the step of translating the position of the first aircraft into an audio signal.

9. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of listening for any conflicting radio frequency signals.

10. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 9 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of waiting a period of time prior to transmission.

11. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 10 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of waiting a predetermined period of time prior to transmission.

12. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 10 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of waiting a random period of time prior to transmission.

13. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 or 10 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of transmitting a radio frequency signal in a non-interrogation manner.

14. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in the frequency range from about and including the VHF band to about and including the SHF band.

15. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in a substantially omnidirectional pattern.

16. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of encoding the position of the first aircraft further comprises the step of encoding an identification code for the first aircraft so that the identification code can be carried by the first radio frequency signal and wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the identification code for the first aircraft.

17. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 further comprising the step of repeating steps (a) through (g).

18. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 17 wherein the step of monitoring the position of the first aircraft comprises the step of repeatedly displaying the position of the first aircraft on a display as the aircraft changes position.

19. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 18 wherein the step of monitoring the position of the first aircraft further comprises the step of displaying the heading and the speed of the first aircraft on a display.

20. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 wherein the step of monitoring the position of the first aircraft comprises the step of displaying the relative position of the first aircraft on a display over a selected period of time.

21. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 1 further comprising the step of determining the location of the second position relative to the fixed reference and wherein the step of monitoring the position of the first aircraft comprises the

step of displaying the position of the first aircraft and the location of the second position.

22. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, the method comprising the steps of:

(a) determining, internally to the first craft using an external automated navigational system, the first craft's position in at least one plane of space;

(b) encoding the first craft's position in a form which can be carried by a first radio frequency signal;

(c) determining when the first radio frequency signal should be transmitted;

(d) transmitting the first radio frequency signal carrying the first craft's position;

(e) receiving the first radio frequency signal at a monitoring receiver of a second craft;

(f) decoding at the monitoring receiver of the second craft the first craft's position from the first radio frequency signal;

(g) displaying the position of the first craft at the monitoring receiver of the second craft; and

(h) repeating steps (a) through (g).

23. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of determining the first craft's position comprises the step of determining the first craft's position using a LORAN receiver.

24. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of determining the first craft's position comprises the step of determining the first craft's position using a GPS receiver.

25. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the first craft's position is defined in reference to the latitude and longitude of the first craft.

26. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 25 wherein the step of determining the first craft's position further comprises the step of determining the altitude of the first craft.

27. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claims 25 or 26 wherein the step of encoding the first craft's position comprises the step of encoding the position of the craft into a digital pulse train.

28. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 27 wherein the step of encoding the position of the first craft's position further comprises the step of translating the position of the craft into an audio signal.

29. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 further comprising the step of avoiding conflicts with any conflicting radio frequency signals in the airspace.

30. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of listening for any conflicting radio frequency signals.

31. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of waiting a period of time prior to transmission.

32. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of waiting a predetermined period of time prior to transmission.

33. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 or 29 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of transmitting a radio frequency signal in a non-interrogation manner.

34. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in the frequency range from about and including the VHF band to about and including the SHF band.

35. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in a substantially omnidirectional pattern.

36. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of encoding the position of the first craft further comprises the step of encoding an identification code for the first craft so that the identification code can be carried by the first radio frequency signal and wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the identification code for the first craft.

37. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 further comprising the step of avoiding conflicts with any conflicting radio frequency signals in the airspace.

38. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of displaying the position of the first craft at the monitoring position comprises the step of repeatedly displaying the position of the first aircraft on a display as the aircraft changes position.

39. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 22 wherein the step of displaying the position of the first craft at the

monitoring position further comprises the step of displaying the heading and the speed of the first craft on a display.

40. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 38 comprises the step of displaying the position of the second craft on a display, the second craft having the monitoring receiver on board

41. A method of tracking the position of a first craft by a monitoring receiver, the first craft and the monitoring receiver being within a predetermined range of each other, as defined in claim 40 further comprising the step of determining the location of the second position relative to the fixed reference and wherein the step of displaying the position of the first craft comprises the step of displaying the position of the first craft and the location of the monitoring receiver on the display.

42. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, the method comprising the steps of:

(a) determining on board the first craft using an existing automated navigational system the first craft's position in at least two perpendicular planes of space which are of interest to the second craft;

(b) encoding the first craft's position in a form which can be carried by a first radio frequency signal;

(c) determining whether the first radio frequency signal will conflict with any other radio frequency signals;

(d) transmitting the first radio frequency signal carrying the first craft's position;

(e) receiving the first radio frequency signal at the second craft;

(f) decoding the first craft's position from the first radio frequency signal;

(g) apprising the operator of the second craft when the position of the first craft is within an advisory range; and

(h) repeating steps (a) through (g).

43. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 42 wherein the step of determining the first craft's position comprises the step of receiving a LORAN signal and determining a position in latitude and longitude.

44. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 42 wherein the step of determining the first craft's position comprises the step of receiving a GPS signal.

45. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 42 wherein existing automated navigational system is available both within and without the predetermined range.

46. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 45 wherein the step of determining the first craft's position comprises the step of determining its position in latitude and longitude.

47. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 45 wherein the step of determining the first craft's position further comprises the step of determining the altitude of the first craft.

48. A method for announcing the position of a first aircraft at a first position to a receiver located at a second position as defined in claim 46 or 47 wherein the step of avoiding conflicts with any conflicting radio frequency signals in the airspace comprises the step of

transmitting a radio frequency signal in a noninterrogation manner.

49. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 46, 47 or 48 wherein the step of encoding the first craft's position comprises the step of encoding the position of the first craft into a digital pulse train.

50. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 49 wherein the step of encoding the position of the first aircraft further comprises the step of translating the first craft's position into an audio signal.

51. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 49 wherein the step of determining whether the first radio frequency signal will conflict with any other radio frequency signals comprises the steps of:

listening for any conflicting radio frequency signals; and

waiting a period of time prior to transmission.

52. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 51 wherein the step of waiting a period of

time comprises the step of waiting a randomly assigned period of time.

53. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 42 wherein the step of encoding the first craft's position comprises the step of encoding an identification code for the first craft so that the identification code can be carried by the first radio frequency signal and wherein the step of transmitting the first radio frequency signal comprises the steps of:

transmitting the first radio frequency signal in the frequency range from about and including the VHF band to about and including the SHF band and frequency signal;

transmitting the first radio frequency signal in a substantially omnidirectional pattern; and

transmitting the identification code for the first craft.

54.^@A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as defined in claim 42 wherein the step of apprising the operator comprises the step of repeatedly displaying the position of the first craft on a display as the first craft changes position.

55. A method of tracking the position of a first craft from on board a second craft, the first and second craft being within a predetermined range of each other, as

defined in claim 54 wherein the step of apprising the operator of the second craft comprises the steps of:

displaying the relative position and direction of travel of the first craft on a display; and

displaying the position of the second craft on a display.

56. A method of avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first and second crafts coming within a predetermined range of each other, the method comprising the steps of:

(a) determining, on board to the first craft and using an existing automated navigational system, the first craft's position in at least one plane in space which is of interest to the second craft to avoid a collision with the first craft;

(b) encoding the first craft's position and identification code to be carried by a first radio frequency signal;

(c) listening for any radio frequency signals present on the same frequency allocation as the first radio frequency signal;

(d) transmitting the first radio frequency signal carrying the first craft's position and identification code;

(e) receiving the first radio frequency signal at the second craft;

(f) decoding the first craft's position and identification code from the first radio frequency signal;

(g) determining the second craft's position, on board the second craft by using an existing automated navigational system, and in at least one dimension of

space, which is of interest to the operator of the second craft, to avoid a collision with the first craft;

(h) displaying, on board the second craft, the position of the first craft and the location of the second craft so that the operator of the second craft is apprised of the location of the both the first craft and the second craft so as to avoid a collision therebetween; and

(i) repeating steps (a) through (h).

57. A method of avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first and second craft coming within a predetermined range of each other, as defined in claim 56 wherein the step of determining the first craft's position comprises the step of receiving a LORAN signal or a GPS signal.

58. A method of avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first and second craft coming within a predetermined range of each other, as defined in claim 57 wherein the first craft comprises an aircraft and wherein the step of determining first craft's position comprises the step of determining the latitude, longitude, and altitude of the first aircraft.

59. A method of avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first and second craft coming within a predetermined range of each other, as defined in claim 56 wherein the step of

encoding the first craft's position comprises the step of encoding the latitude and longitude of the first craft into a digital pulse train which can be carried by a frequency modulated first radio frequency signal.

60. A method of avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first and second craft coming within a predetermined range of each other, as defined in claim 56 further comprises the step of step of waiting a period of time after a conflicting radio frequency signal is heard prior to transmission of the first radio frequency signal, the period of time being different for the first craft and the second craft, the transmission of the first radio frequency signal being initiated without interrogation from another radio frequency signal.

61. A method of avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first and second craft coming within a predetermined range of each other, as defined in claim 56 wherein the step of transmitting the first radio frequency signal comprises the step of transmitting the first radio frequency signal in the frequency range from about and including the VHF band to about and including the SHF band in a substantially omnidirectional pattern.

62. A method of avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first and second craft coming within a predetermined range of each other, as defined in claim 56 wherein the step of

displaying the position of the first craft comprises the step of displaying the relative direction of travel of the first craft on a display.

63. An apparatus for announcing the position of a first aircraft at a first position within airspace capable of containing a plurality of other aircraft, to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, the apparatus comprising:

means for making an on board determination of the position of the first aircraft using the existing navigational system;

means for encoding the position of the first aircraft into information which can be carried by a first radio frequency signal;

means for detecting the presence of any conflicting radio frequency signal which would interfere with the first radio frequency signal and determining whether transmission of the first radio frequency should proceed;

means for transmitting the first radio frequency signal, from the first aircraft, carrying the position information of the first aircraft such that the radio frequency signal can be received at the receiver, decoded, and the position of the first aircraft announced at the receiver.

64. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range

of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for making an on board determination of the position of the first aircraft comprises a LORAN receiver.

65. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for making an on board determination of the position of the first aircraft comprises a GPS receiver.

66. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for making an on board determination of the position of the first aircraft comprises means for determining the latitude and longitude of the first aircraft.

67. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 66 wherein the means for making an on

board determination of the position of the first aircraft further comprises means for determining the altitude of the aircraft.

68. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for transmitting the first radio frequency signal comprises a radio frequency transmitter operating in a frequency range from about and including the VHF band to about and including the SHF band.

69. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 68 wherein the means for transmitting the first radio frequency signal further comprises an omnidirectional antenna.

70. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for detecting the presence of any conflicting radio frequency signal comprises a radio frequency receiver.

71. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 wherein the means for encoding the position of the first aircraft is further for encoding an identification code into information which can be carried by the first radio frequency signal.

72. An apparatus for announcing the position of a first aircraft at a first position to a receiver located at a second position within a predetermined range of the first aircraft, the first aircraft being within operational range of an existing navigational system which can provide position information in at least two planes of interest, as defined in claim 63 further comprising:

means for receiving a second radio frequency signal carrying the position and identification code for a second aircraft;

means for decoding the second aircraft's position and identification code from the second radio frequency signal; and

means for displaying, on board the first aircraft, the second aircraft's position and identification code decoded from the second radio frequency signal so that the operator of the first craft is apprised of the position of the second aircraft.

73. An apparatus for tracking the position of a second craft from on board a first craft, the first and the second craft being within range of an existing navigational system and within a predetermined range of each other, the apparatus comprising:

means, on board the first craft, for receiving a determination of the position of the first craft using the existing navigational system, the position of the first craft being determined in at least two planes of interest to the operator of the second craft;

means for encoding the first craft's position in a form which can be carried by a first radio frequency signal;

means for transmitting the first radio frequency signal carrying the first craft's position;

means for receiving a second radio frequency signal carrying the second craft's position;

means for decoding the second craft's position from the second radio frequency signal;

means for displaying, on board the first craft, the second craft's position decoded from the second radio frequency signal so that the operator of the first craft is apprised of the position of the second craft.

74. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 73 wherein the means for receiving an on board determination of the position of the first craft comprises a data port adapted to receive data from a LORAN receiver.

75. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 73 wherein the means for receiving an on board determination of the position of the first craft comprises a data port adapted to receive data from a GPS receiver.

76. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 73 wherein the means for transmitting the first radio frequency signal comprises:

a radio frequency transmitter operating in a frequency range from about and including the VHF band to about and including the SHF band; and

an omnidirectional antenna system.

77. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 76 wherein the means for detecting the presence of any conflicting radio frequency signal comprises a radio frequency receiver.

78. An apparatus for tracking the position of a second craft from on board a first craft as defined in claim 77 wherein the means for encoding the first craft's position is further for encoding an identification code into information which can be carried by the first radio frequency signal.

79. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code, the first craft being within range of an existing navigational system and the first and the second craft being within a

predetermined range of each other, the apparatus comprising:

means for determining, on board the first craft and using the existing navigational system, the first craft's position in at least one plane in space which is of interest to the second craft to avoid a collision with the first craft;

means for encoding the first craft's position and the first identification code to be carried by a first radio frequency signal;

means for detecting the presence of any conflicting radio frequency signal and determining whether transmission of the first radio frequency should proceed;

means for transmitting the first radio signal carrying the first craft's position and identification code;

means for receiving, on board the first craft, a second radio frequency signal transmitted from the second craft, the second radio frequency signal carrying the position of the second craft and the second identification code;

means for decoding, on board the first craft, the second craft's position and identification code;

means for simultaneously displaying the first craft's position and the second craft's position on board the first craft so that the operator of the first craft is apprised of the position of the second craft so as to avoid a collision therebetween.

80. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 79 where in the means for determining the first craft's position comprises a LORAN receiver.

81. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 79 where in the means for determining the first craft's position comprises a GPS receiver.

82. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 80 or 81 wherein the means for transmitting the first radio frequency signal comprises:

a radio frequency transmitter operating in a frequency range from about and including the VHF band to about and including the SHF band; and

an omnidirectional antenna system.

83. An apparatus for avoiding collisions between a first craft having a first identification code and at least a second craft having a second identification code as defined in claim 82 wherein the means for detecting the presence of any conflicting radio frequency signal comprises a radio frequency receiver.

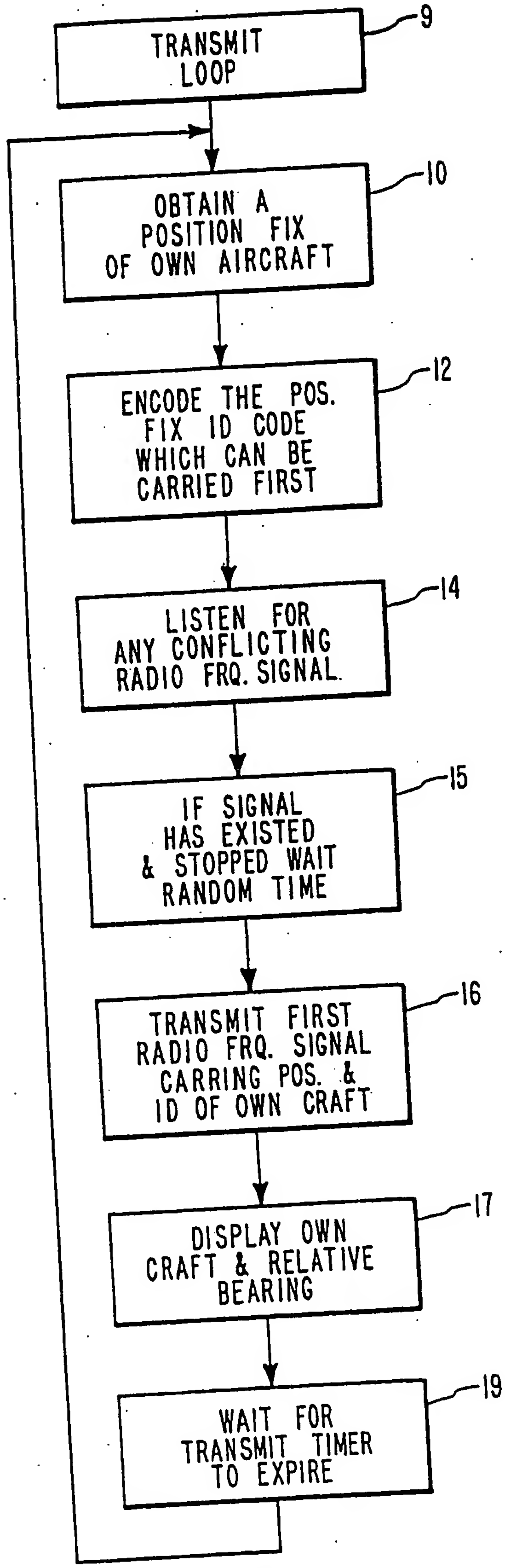
TRANSMIT LOOP
9
OBTAIN A POSITION FIX OF OWN AIRCRAFT
10
ENCODE THE POS. FIX ID CODE WHICH CAN BE CARRIED FIRST
12
LISTEN FOR ANY CONFLICTING RADIO FRQ. SIGNAL
14
IF SIGNAL HAS EXISTED & STOPPED WAIT RANDOM TIME
15
TRANSMIT FIRST RADIO FRQ. SIGNAL CARRING POS. & ID OF OWN CRAFT
16
DISPLAY OWN CRAFT & RELATIVE BEARING
17
WAIT FOR TRANSMIT TIMER TO EXPIRE
19

FIG. 1A

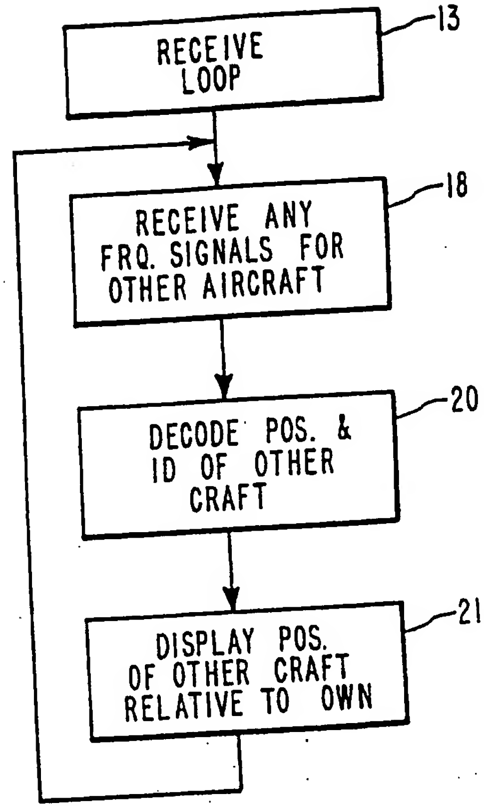
RECEIVE LOOP
13
RECEIVE ANY FRQ. SIGNALS FOR OTHER AIRCRAFT
18
DECODE POS. & ID OF OTHER CRAFT
20
DISPLAY POS. OF OTHER CRAFT RELATIVE TO OWN
21

FIG. 1B

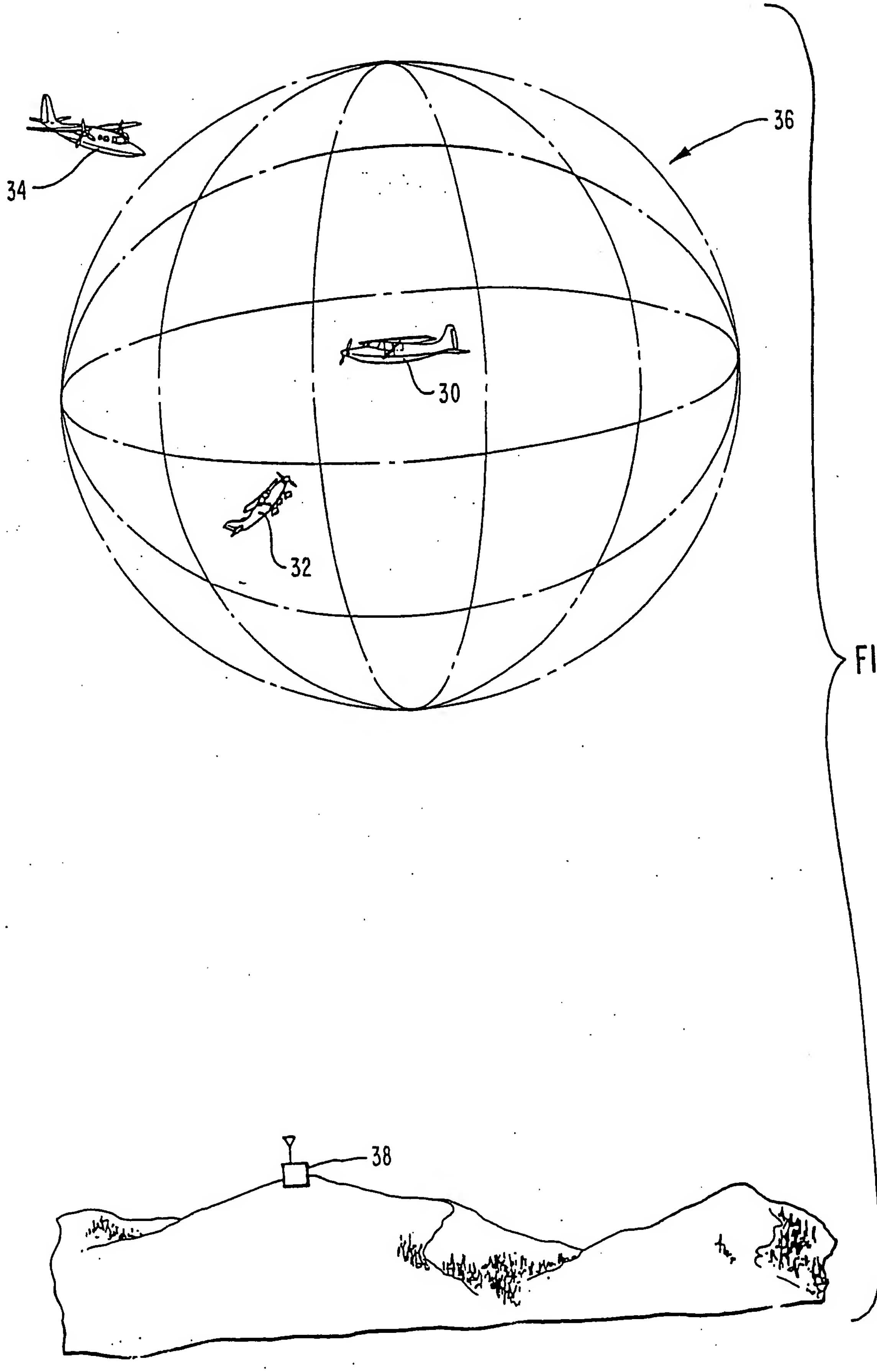

FIG. 2

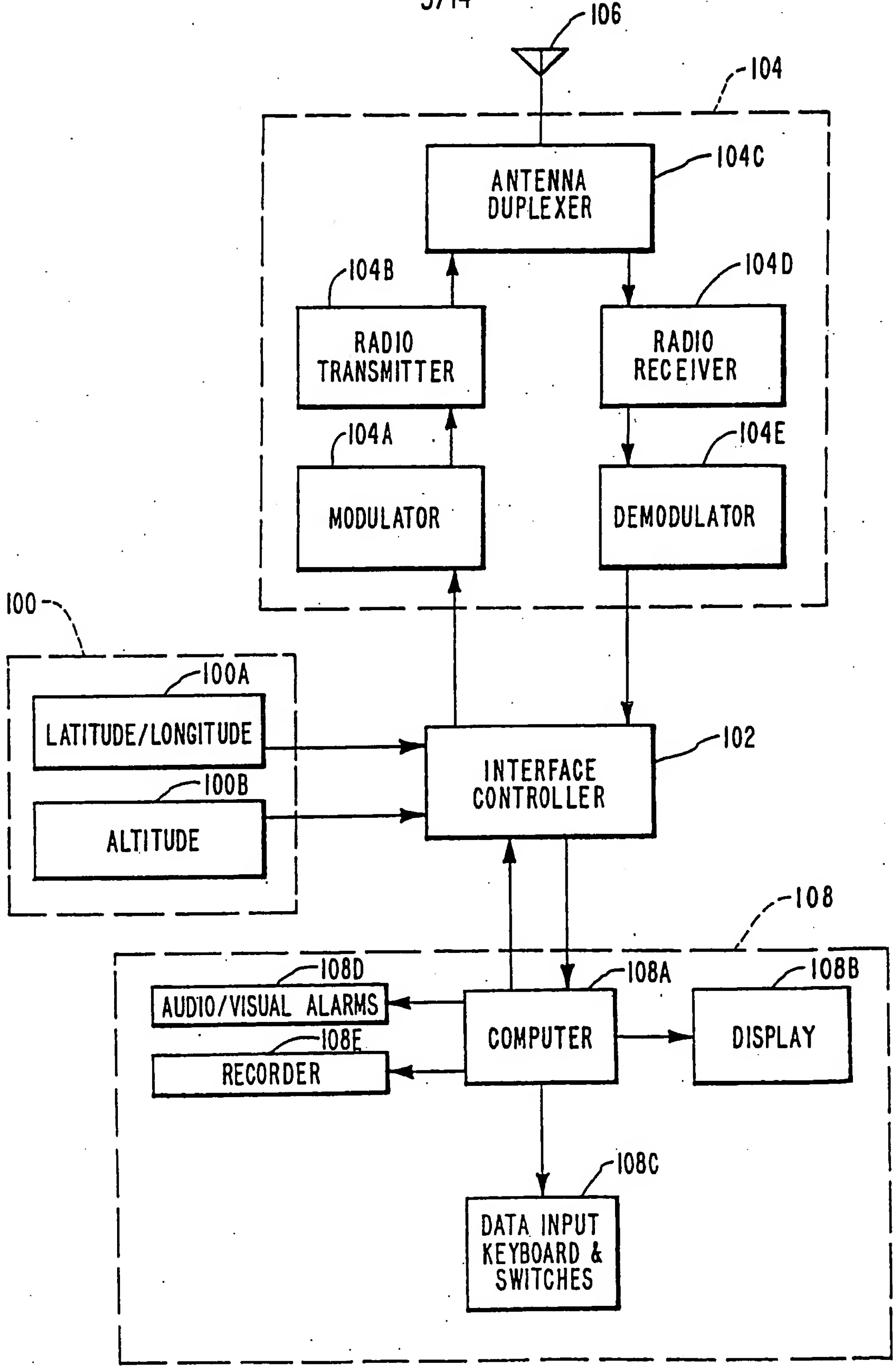
106
104
ANTENNA DUPLEXER
104C
104B
RADIO TRANSMITTER
104D
RADIO RECEIVER
104A
MODULATOR
104E
DEMODULATOR
100
100A
LATITUDE/LONGITUDE
100B
ALTITUDE
INTERFACE CONTROLLER
102
108
108D
AUDIO/VISUAL ALARMS
108E
RECORDER
108A
COMPUTER
108B
DISPLAY
108C
DATA INPUT KEYBOARD & SWITCHES

FIG. 3

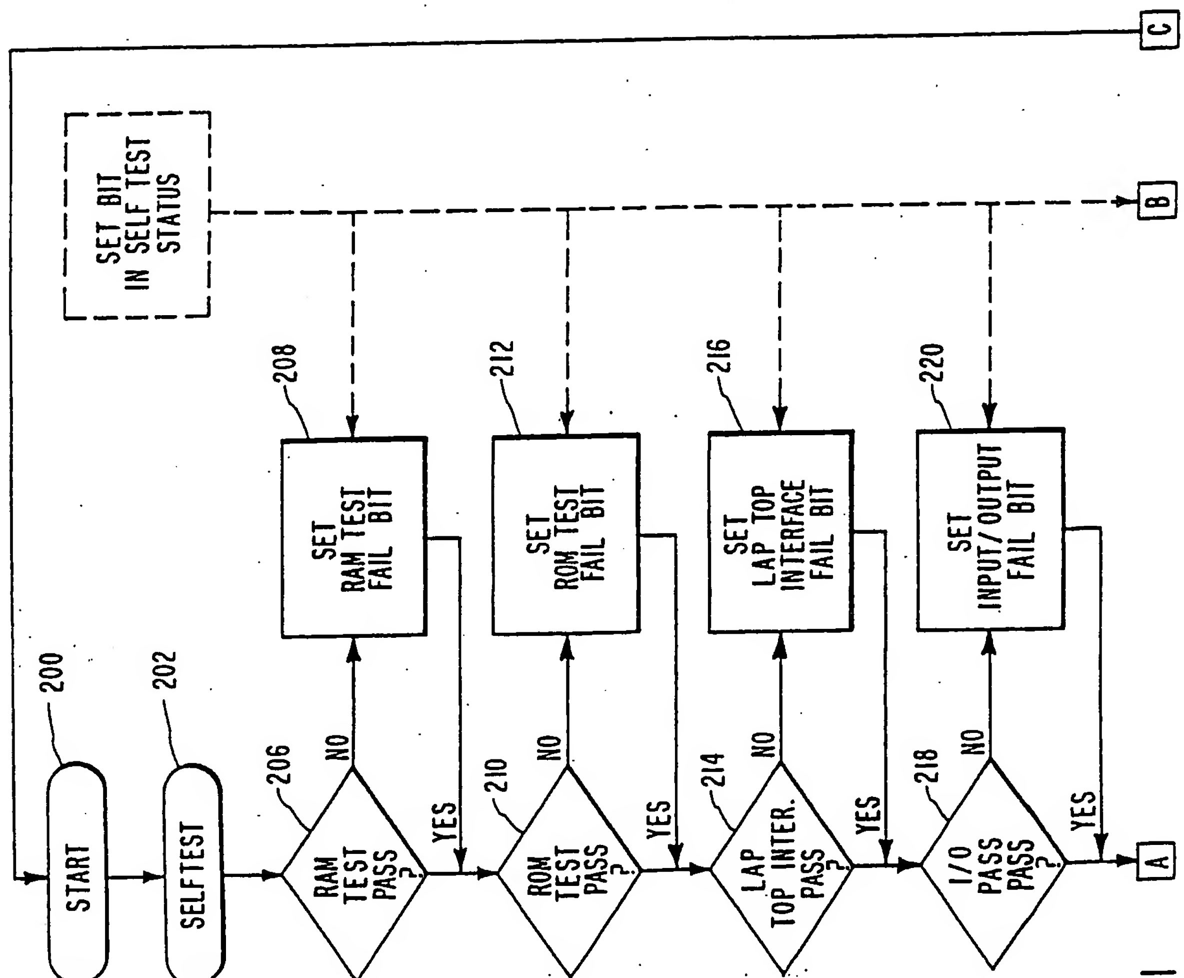
START
200
SELFTEST
202
RAM TEST PASS ?
206
NO
YES
SET RAM TEST FAIL BIT
208
ROM TEST PASS ?
210
SET ROM TEST FAIL BIT
212
LAP TOP INTER. PASS ?
214
SET LAP TOP INTERFACE FAIL BIT
216
I/O PASS PASS ?
218
SET INPUT/OUTPUT FAIL BIT
220
SET BIT IN SELF TEST STATUS
A
B
C

FIG. 4-1

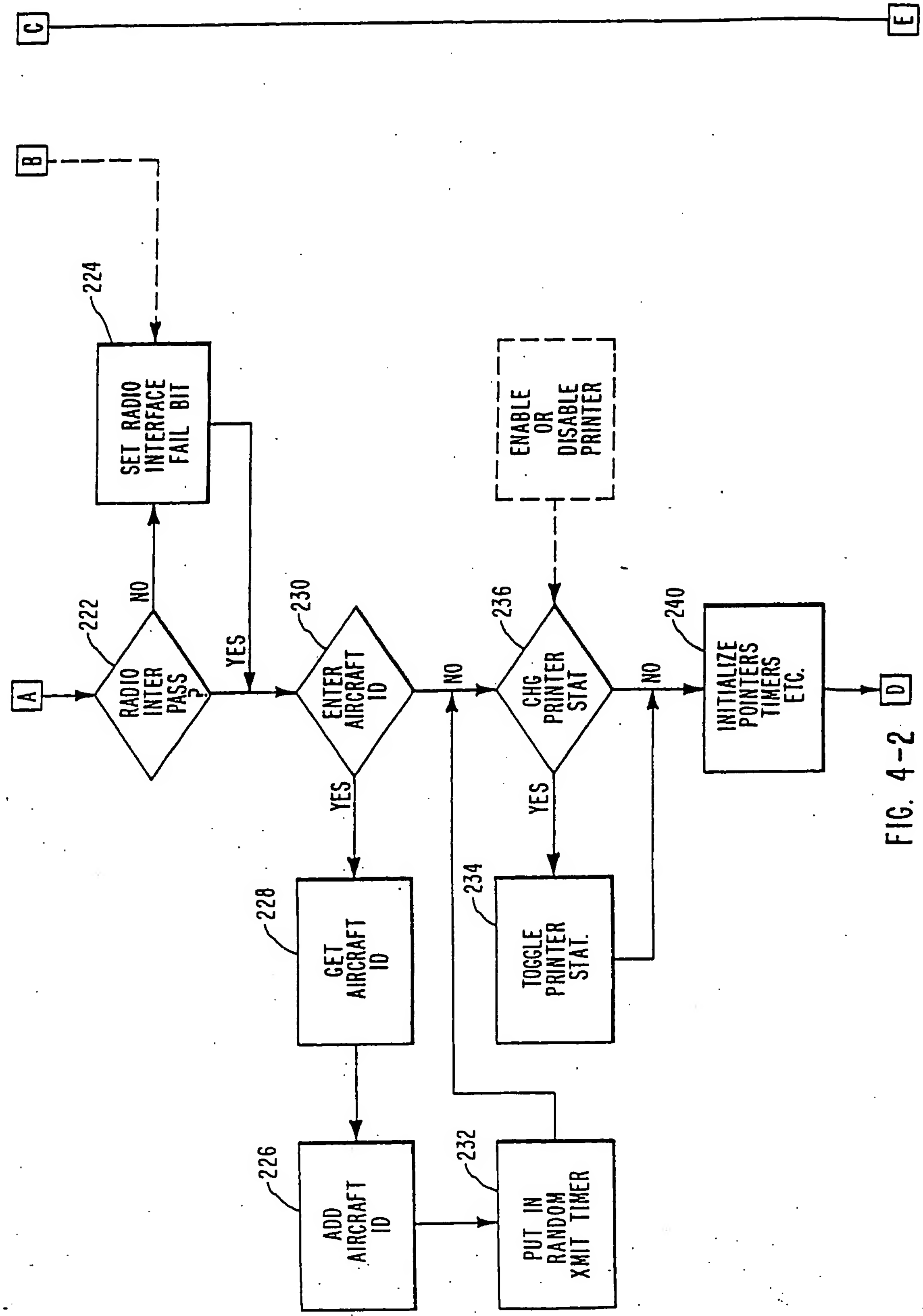
C
E
B
A
222
RADIO INTER PASS ?
NO
224
SET RADIO INTERFACE FAIL BIT
YES
230
ENTER AIRCRAFT ID
YES
228
GET AIRCRAFT ID
226
ADD AIRCRAFT ID
232
PUT IN RANDOM XMIT TIMER
NO
ENABLE OR DISABLE PRINTER
236
CHG PRINTER STAT
YES
234
TOGGLE PRINTER STAT.
NO
240
INITIALIZE POINTERS TIMERS ETC.
D

FIG. 4-2

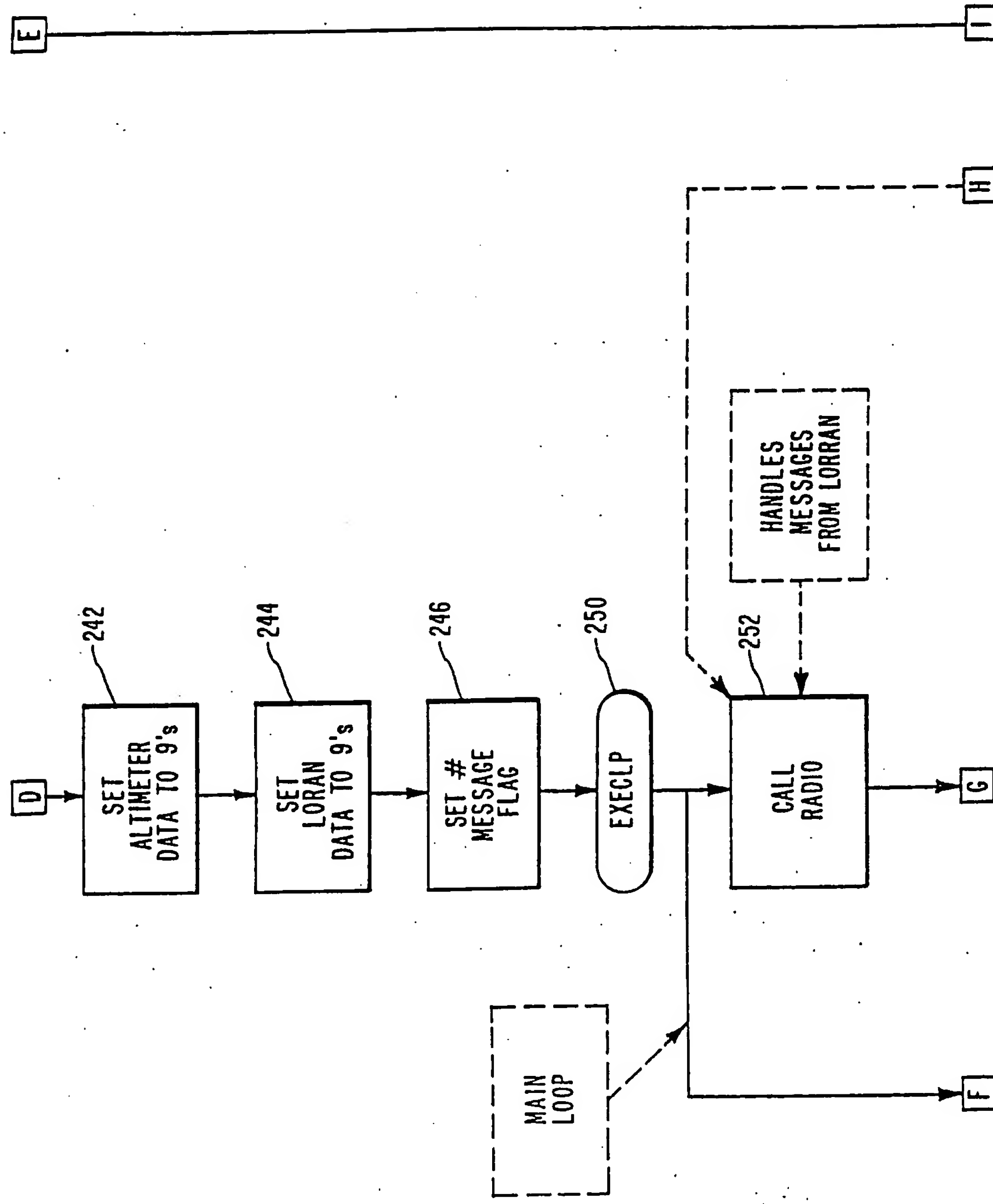
E
I
H
D
SET ALTIMETER DATA TO 9's
242
SET LORAN DATA TO 9's
244
SET # MESSAGE FLAG
246
EXECLP
250
CALL RADIO
252
HANDLES MESSAGES FROM LORRAN
G
MAIN LOOP
F

FIG. 4-3

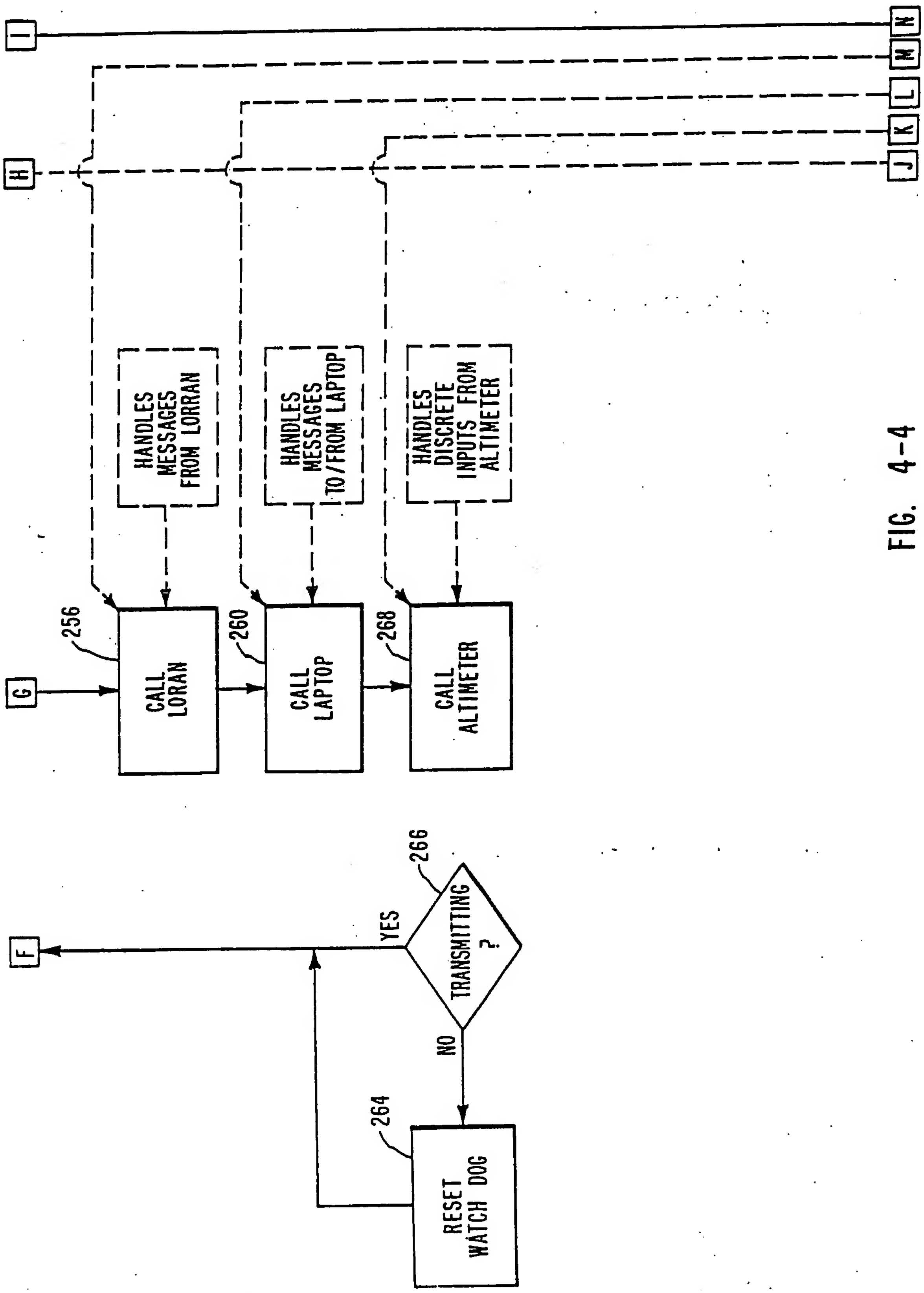
I
H
N
M
L
K
J
HANDLES MESSAGES FROM LORRAN
HANDLES MESSAGES TO/FROM LAPTOP
HANDLES DISCRETE INPUTS FROM ALTIMETER
G
256
CALL LORAN
260
CALL LAPTOP
268
CALL ALTIMETER
F
YES
266
TRANSMITTING ?
NO
264
RESET WATCH DOG

FIG. 4-4

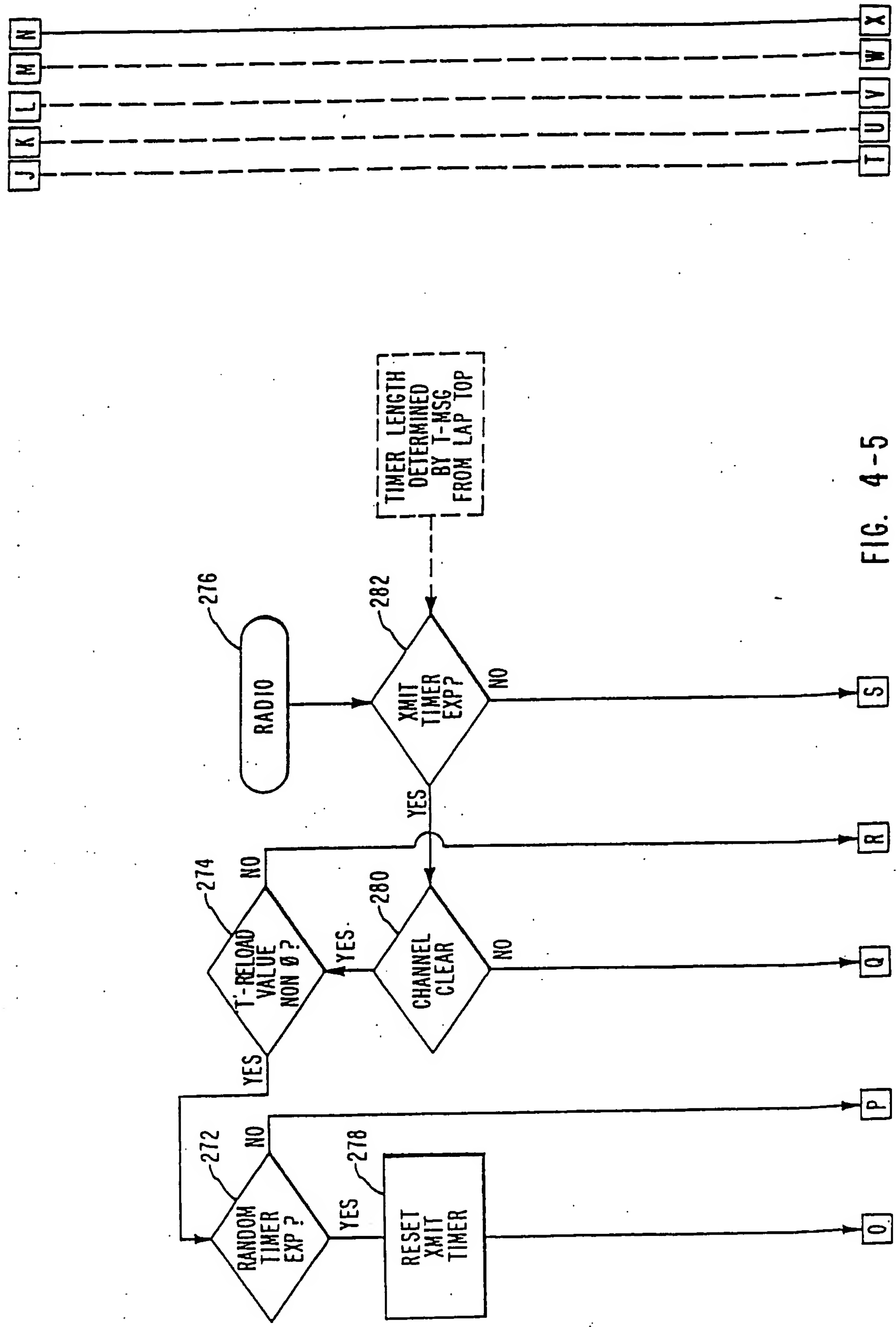
J
K
L
M
N
T
U
V
W
X
TIMER LENGTH DETERMINED BY T-MSG FROM LAP TOP
276
RADIO
282
XMIT TIMER EXP?
NO
YES
S
R
274
T-RELOAD VALUE NON Ø ?
NO
YES
280
CHANNEL CLEAR
NO
YES
Q
272
RANDOM TIMER EXP ?
NO
YES
278
RESET XMIT TIMER
P
O

FIG. 4-5

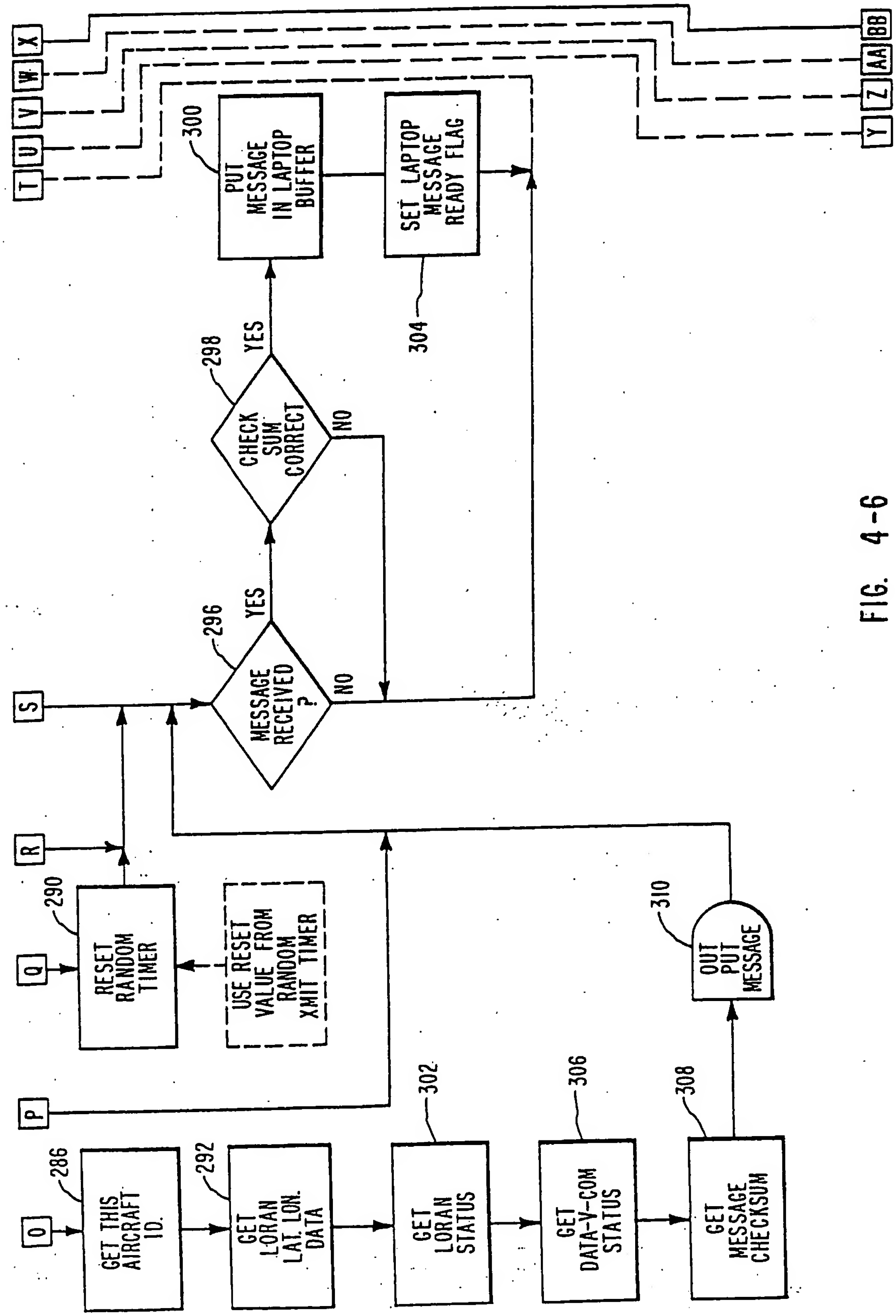
O
GET THIS AIRCRAFT ID.
286
GET LORAN LAT. LON. DATA
292
GET LORAN STATUS
302
GET DATA-V-COM STATUS
306
GET MESSAGE CHECKSUM
308
OUT PUT MESSAGE
310
P
Q
RESET RANDOM TIMER
290
USE RESET VALUE FROM RANDOM XMIT TIMER
R
S
MESSAGE RECEIVED ?
296
YES
NO
CHECK SUM CORRECT
298
YES
NO
PUT MESSAGE IN LAPTOP BUFFER
300
SET LAPTOP MESSAGE READY FLAG
304
T
U
V
W
X
BB
AA
Z
Y

FIG. 4-6

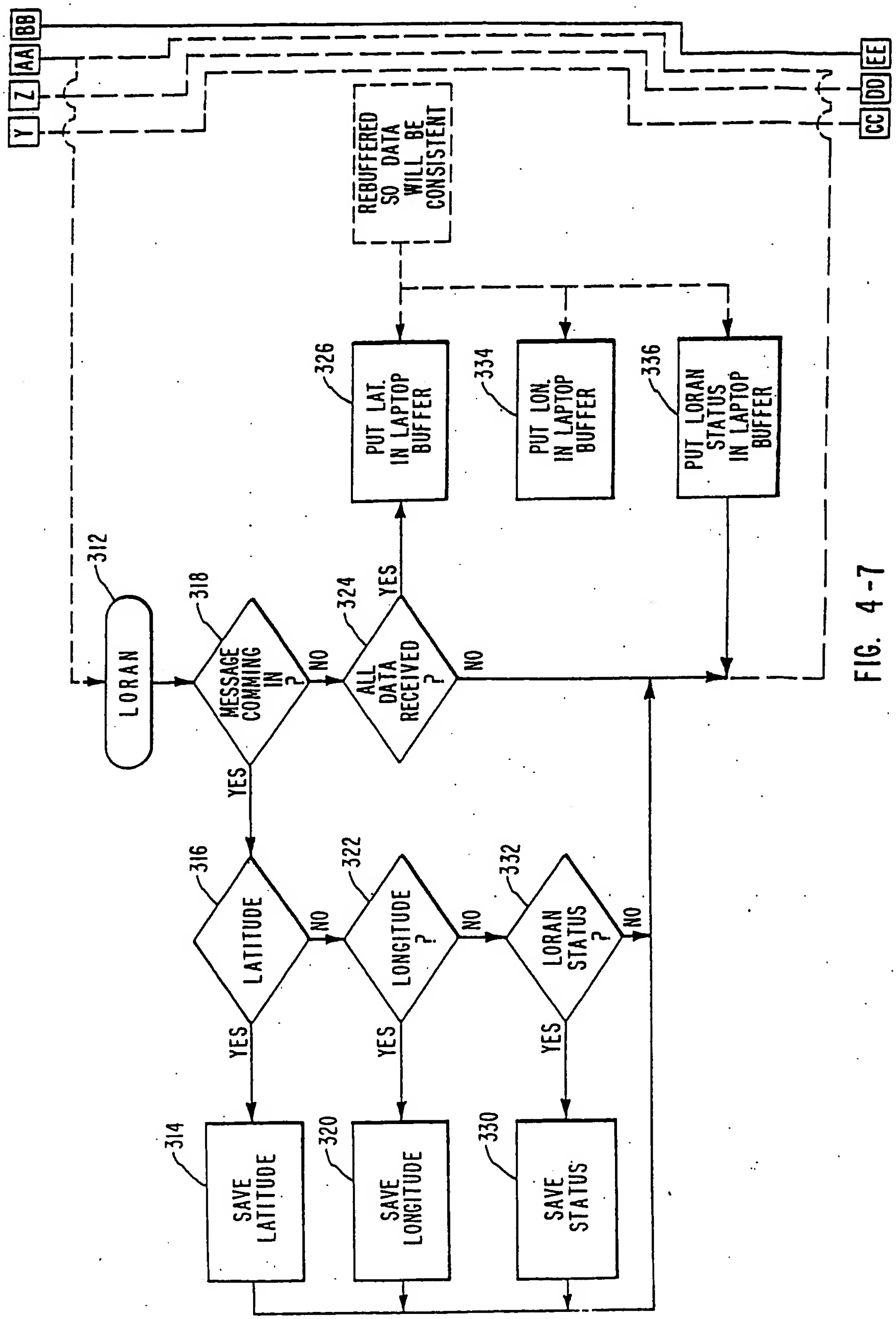
Y
Z
AA
BB
CC
DD
EE
REBUFFERED SO DATA WILL BE CONSISTENT
312
LORAN
318
MESSAGE COMMING IN ?
NO
YES
324
ALL DATA RECEIVED ?
YES
NO
326
PUT LAT. IN LAPTOP BUFFER
334
PUT LON. IN LAPTOP BUFFER
336
PUT LORAN STATUS IN LAPTOP BUFFER
316
LATITUDE
322
LONGITUDE ?
332
LORAN STATUS ?
314
SAVE LATITUDE
320
SAVE LONGITUDE
330
SAVE STATUS

FIG. 4-7

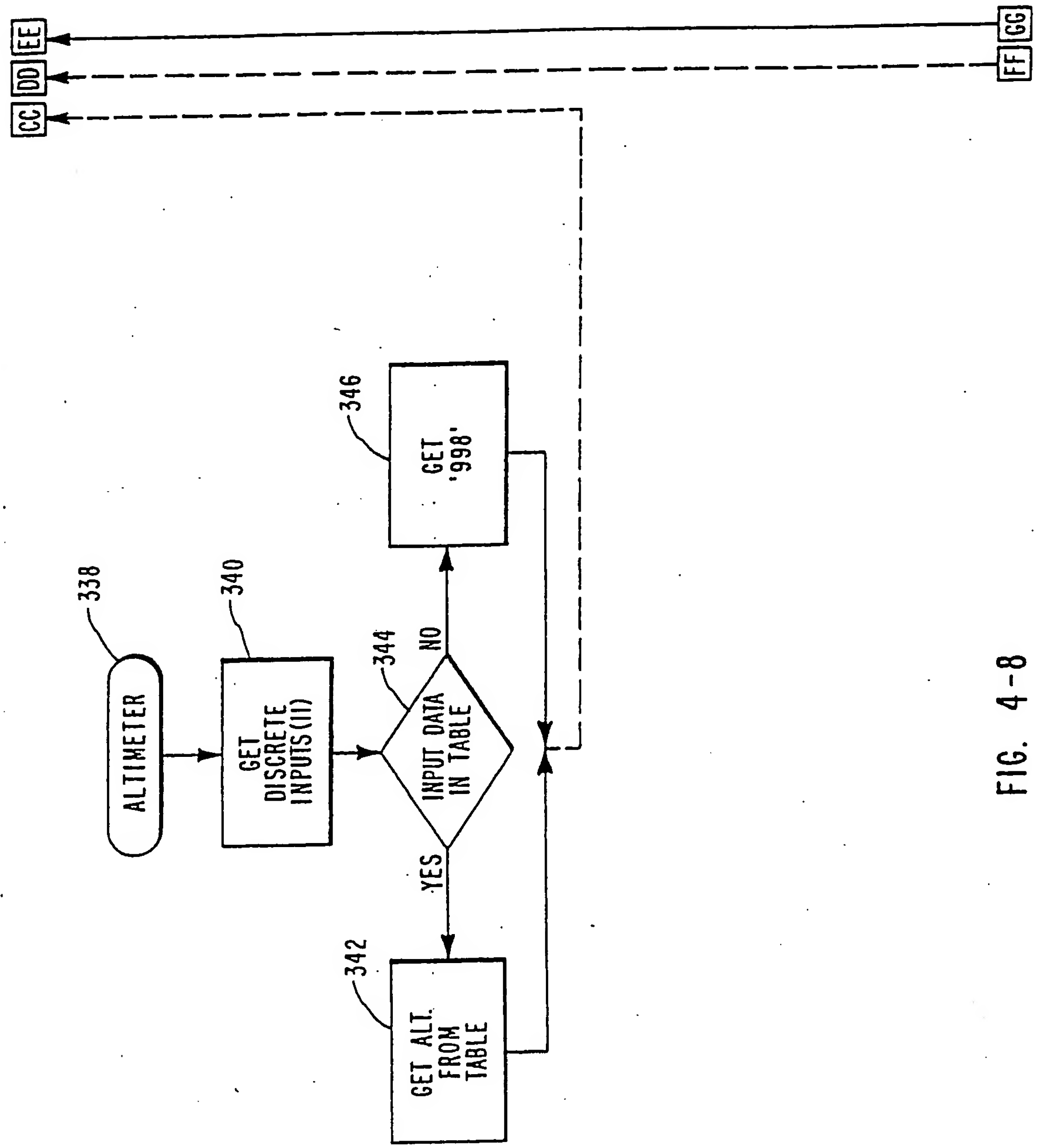
ALTIMETER
338
GET DISCRETE INPUTS(II)
340
INPUT DATA IN TABLE
344
YES
NO
GET ALT. FROM TABLE
342
GET '998'
346
CC
DD
EE
FF
GG

FIG. 4-8

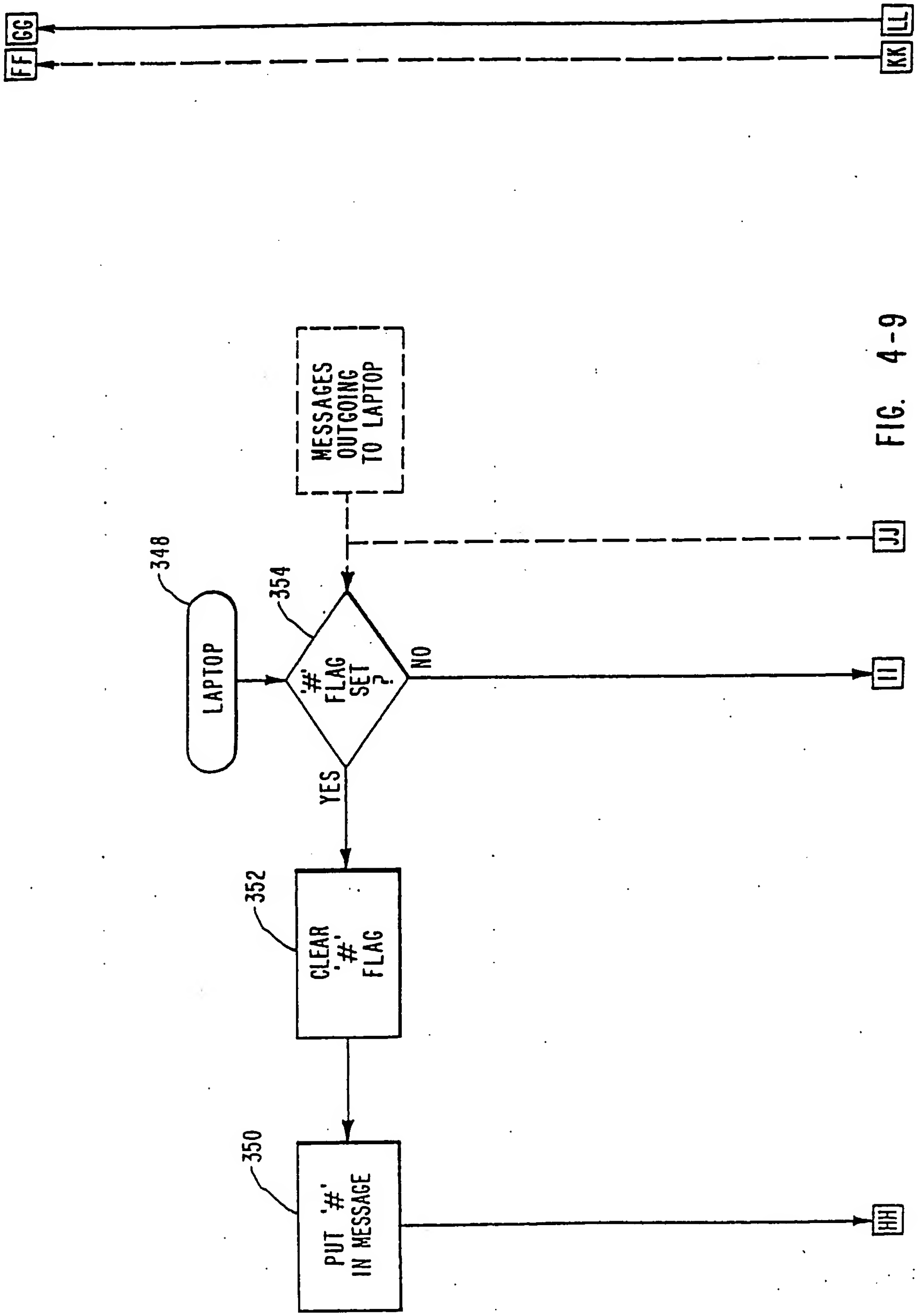
FF
GG
LL
KK
MESSAGES OUTGOING TO LAPTOP
JJ
348
LAPTOP
354
'#' FLAG SET ?
NO
II
YES
352
CLEAR '#' FLAG
350
PUT '#' IN MESSAGE
HH

FIG. 4-9

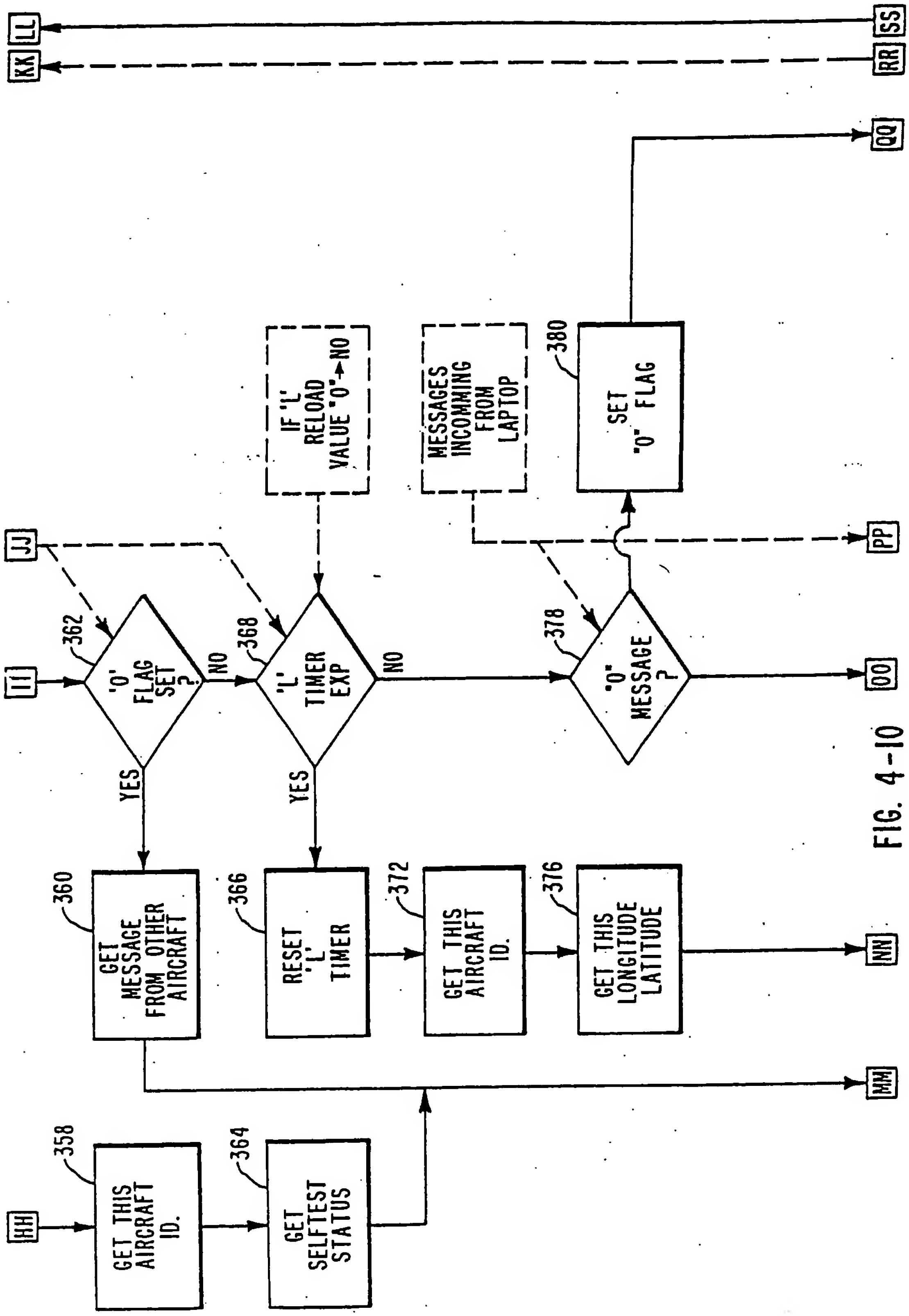
HH
GET THIS AIRCRAFT ID.
358
GET SELFTEST STATUS
364
MM
II
'O' FLAG SET ?
362
YES
NO
GET MESSAGE FROM OTHER AIRCRAFT
360
JJ
'L' TIMER EXP
368
YES
NO
RESET 'L' TIMER
366
GET THIS AIRCRAFT ID.
372
GET THIS LONGITUDE LATITUDE
376
NN
IF 'L' RELOAD VALUE "O"→NO
MESSAGES INCOMMING FROM LAPTOP
"O" MESSAGE ?
378
OO
PP
SET "O" FLAG
380
QQ
KK
LL
RR
SS

FIG. 4-10

INTERNATIONAL SEARCH REPORT

International Application No PCT/US91/05738

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): G01S 3/02
US CL : 364/452,461; 340/961; 342/29,41,455

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
U.S.	364/452,459,460,461 340/961 342/29,30,31,32,41,450,451,455,463

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched

III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	US, A, 4,835,537 (MANION) 30 MAY 1989 See figs. 1,3,5,7,8 and cols. 2-5,7 ,11-14.	1-83
A	US, A, 5,043,903 (CONSTANT) 27 AUGUST 1991	
A	US, A, 3,750,166 (DEARTH) 31 JULY 1973	
A	US, A, 4,884,208 (MARINELLI ET AL.) 28 NOVEMBER 1989	

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
19 NOVEMBER 1991	25 NOV 1991
International Searching Authority	**Signature of Authorized Officer**
ISA/US	GARY CHIN

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